CENTRAL LAKE ONTARIO CONSERVATION REPORT

WATER

ONTARIO

DEPARTMENT OF ENERGY AND RESOURCES MANAGEMENT

CONSERVATION AUTHORITIES BRANCH

DEPARTMENT OF ENERGY AND RESOURCES MANAGEMENT

HON. J. R. SIMONETT
Minister

T. R. HILLIARD
Deputy Minister

A. S. L. BARNES
Director, Conservation Authorities Branch

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ONTARIO

TORONTO
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AUTHORSHIP

This report was prepared under the direction of the present staff of the Conservation Authorities Branch, but much of the preliminary work was done by A. F. Smith, P. Eng., a former member of our staff.

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RECOMMENDATIONS

STATED OR IMPLIED IN THIS REPORT

1. That the Authority undertake a program of bank stabilization to halt erosion and reduce pollution and sedimentation of streams. (Page 11)

2. That the "regional flood" be used for the design of flood control works and the outlining of flood-vulnerable areas. (Page 19)

3. That a flood warning system be established to minimize flood damage and protect residents living in hazardous areas. (Page 24)

4. That the Authority acquire or encourage municipalities to zone flood plain lands as indicated on the flood plain maps to restrict the use of lands which are subject to flooding. The zoning should provide for recreation, wildlife or agricultural uses commensurate with the flood hazard. (Page 30)

5. That the Authority acquire potential reservoir sites in order that the areas may be preserved for water storage purposes. (Page 32)

6. That the Authority promote a program of channel improvements to ensure that the channels are kept clear and that adequately sized culverts and bridges are used to permit the free passage of flood waters. (Page 35)

7. That the Authority acquire existing mill ponds and suitable sites for community ponds throughout the area. (Page 37)

CHAPTER 1

GENERAL

1. Introduction

The Central Lake Ontario Conservation Authority covers a rectangular area of about 242 square miles. It is located on the north shore of Lake Ontario, about 30 miles east of Metropolitan Toronto, at the easterly extremity of the rich industrial area commonly referred to as the "Golden Horseshoe".

This section of the conservation report is concerned with the streams in the area which were surveyed during the summers of 1959-61 and the problems attendant thereon.

2. Scope of Report

Field surveys made for this study were of a reconnaissance nature but were considered sufficient to define the water problems of the area and permit recommendations for their solution. Levels were run between known Geodetic Survey of Canada bench marks, and a large number of intermediate bench marks were established throughout the area. Descriptions and elevations of these are available from the Conservation Authorities Branch.

Existing mapping, such as the topographical mapping at a scale of 200 feet = 1 inch with 2-foot contours, furnished by the City of Oshawa and the Township of Darlington, aided greatly in determining the flood plains and reservoir storage areas in these particular sections.

Where large-scale mapping was not available, more detailed ground surveys were made to prepare contour plans and determine reservoir storages and stream gradients. Aerial photographs and mosaics were also used to a large extent to outline the flood plains.

It was concluded that the area under study was not experiencing any immediate, pressing water problems such as severe flooding or drought. However, with the rapid expansion of urban development, particularly in the Oshawa and

Bowmanville areas, flooding will become more and more a distressing problem unless adequate precautions are taken to restrict the development and use of the low-lying lands adjacent to the streams. The small watersheds of the Central Lake Ontario Authority are particularly vulnerable to intense storms of short duration. It was a similar situation which gave rise to the disaster in Timmins, Ontario, in 1961, which caused the loss of five lives.

Where the topography is suitable, stream control by means of storage reservoirs is usually recommended since this method provides for the full use of the available water. However, at present, in the Central Lake Ontario watersheds the cost of storage reservoirs is out of proportion to the flood control benefit to be derived. Therefore, in this report the emphasis has been placed on flood plain zoning as the most economical solution to the flood problem.

3. Description of Area

The main topographic features are the Oak Ridges moraine along the northerly boundary with gradations from morainic deposits to sand plains at the old Lake Iroquois shoreline to clay plains extending to the present shoreline of Lake Ontario. These features are shown on the physiography map in the Land section of the conservation report.

The land slopes from an elevation of approximately 1,100 feet above sea level in the north to an elevation of 245-275 feet above sea level along Lake Ontario. This is equivalent to an average surface slope of about 65 feet per mile. However, the surface slopes in the more rugged headwater areas are steeper than those in the lacustrine sand and clay plains to the south.

The shoreline is a series of low cliffs and gravel bars cutting off marshy bays at the outlets of the major streams. These are quite prominent features at the outlets of Pringle, Oshawa, Farewell and Bowmanville Creeks and provide

sheltered harbours for commercial and pleasure boats. The cliffs are generally low, ranging to about 30 feet in height on the more exposed sections of the shoreline.

The soils vary from pervious in the rough hills along the north boundary to semi-pervious and impervious in the southerly portions of the watershed. The volume and rate of runoff varies with the soil types, being greater on the more impervious types, other factors being equal. However, the slope, condition of the soil (whether dry, wet or saturated) and surface cover must all be taken into account. Much of the precipitation in the headwater areas seeps into the ground and to a large extent this modifies the stream flows by reducing peak runoffs and sustaining flows during periods of drought.

Surface cover is also an important consideration from the point of view of runoff. Less than ten per cent of this area remains in natural woodland and there is little likelihood of the forest cover being expanded beyond 15 or 20 per cent.

4. Drainage Systems

There are five main drainage systems in the Authority area, namely the Lynde, Pringle, Oshawa, Farewell and Bowmanville Creeks. Harmony Creek and Soper Brook are major tributaries of the latter two creeks respectively. In addition, there are a number of smaller creeks with drainage areas varying from about two to eight square miles which empty directly into Lake Ontario. These include Corbett, Tooly, Darlington and a number of smaller unnamed creeks.

The configuration of these streams and their respective drainage areas are shown on the accompanying watershed map, Figure 1, and the major streams are described in further detail below.

(a) Bowmanville Creek

Bowmanville Creek, with its main tributary Soper Brook, has a drainage area of 64.5 square miles and is the


CENTRAL LAKE ONTARIO WATERSHEDS
-LEGEND-
RESERVOIR SURVEYED
RESERVOIR INVESTIGATED
STREAM GAUGE
FLOOD PLAIN LAND STUDIED
SCALE
1
½
0
1
2
MILES
UPPER DEVILS DEN
DEVILS DEN
UPPER AIRPORT
LOWER AIRPORT
UPPER GAUD
LOWER GAUD
BOWMANVILLE
Brooklin
ABANDONED
WHITEX
OSHAWA
Courtice
Black
Harmony
Goodm
Tyrone

FIG. 1

largest in the area under study. The main branch rises in the height of land about $1\frac{1}{2}$ miles west of Burketon Station at elevation 1,025 feet and flows south-easterly for a distance of 17.5 miles to its outlet into Lake Ontario at Port Darlington. It has a total fall of 755 feet for an average gradient of 43 feet per mile.

Soper Brook drains an area of about 30 square miles on the easterly edge of the Authority area. It flows southerly through Stephen Gulch to its confluence with the main branch in the marshy bay about $1\frac{1}{2}$ miles upstream from Lake Ontario. This tributary has an overall length of 13 miles and an average gradient of 55 feet per mile.

(b) Lynde Creek

Lynde Creek drains the westerly portion of the Authority area and with a total drainage area of nearly 50 square miles is the second largest of the drainage systems. Its main source is Chalk Lake, one of a series of kettle lakes found along the moraine divide between Georgian Bay and Lake Ontario. From Chalk Lake the stream flows south-east to Brooklyn, thence south, emptying into Lake Ontario at a point about one mile west of Whitby Harbour.

This creek has two comparatively large tributaries which drain the western section of its watershed. The larger one rises about $1\frac{1}{2}$ miles south of Chalk Lake and flows southward to join the main branch 1,000 feet north of Highway 2.

The main branch has a total fall of 714 feet over a length of about 19 miles or an average gradient of approximately 38 feet per mile.

(c) Oshawa Creek

Oshawa Creek drains a funnel-shaped area of 45.6 square miles in the central part of the Authority area. It has two major branches which join at North Oshawa Station, each of which has several headwater tributaries rising in the moraine ridge to the north. The main branch rises in the vicinity of

Myrtle Station and flows south-east through the city of Oshawa to its mouth on Lake Ontario at Lakeview Park.

The east branch rises in the vicinity of Mount Carmel and flows south to its confluence with the main branch at North Oshawa Station.

These streams have an average gradient of 37 feet per mile.

(d) Farewell Creek

Farewell Creek with its major tributary Harmony Creek drains an area of 41.2 square miles lying between the Oshawa and Bowmanville Creek watersheds. Headwaters of this stream are located in the till plain well south of the moraine ridge.

Rising in Concession VII, Darlington Township, the main branch flows south for a distance of 2 miles, due east for a distance of 1 mile to Solina, thence south-west to a large open-water bay on Lake Ontario just west of the Whitby East-Darlington township line. It has an overall length of 12 miles and an average gradient of about 47 feet per mile.

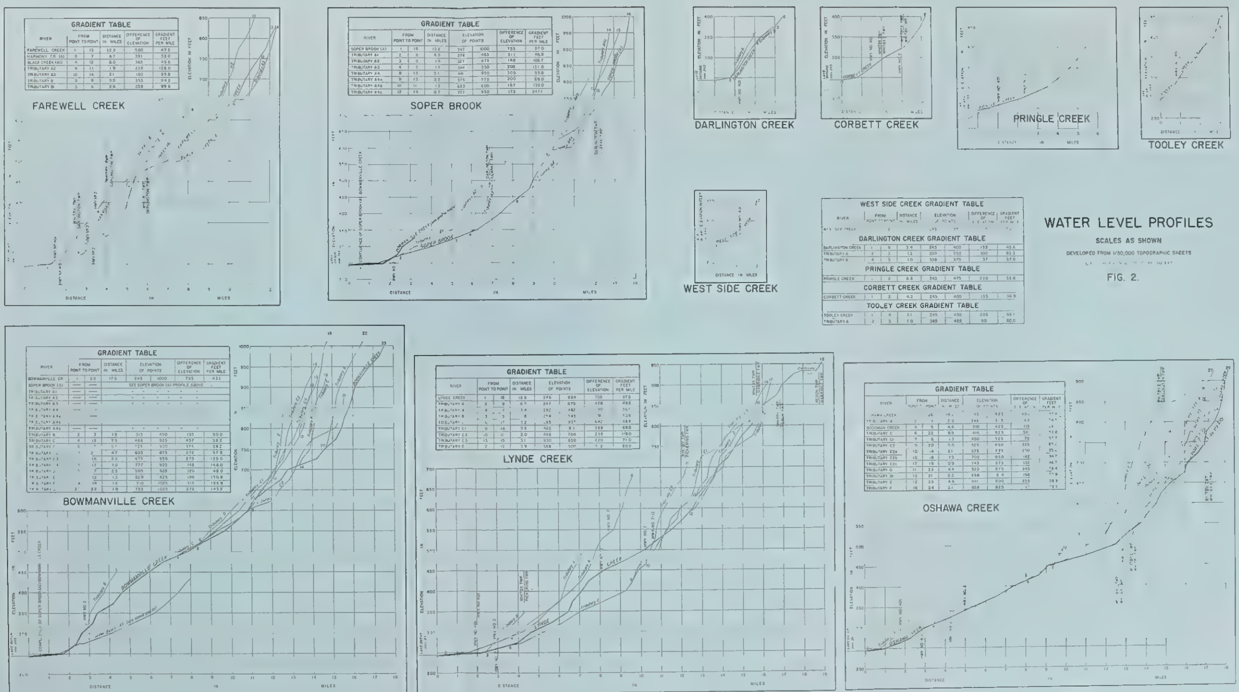
Harmony Creek rises in the vicinity of Taunton and flows southward for a distance of 8.5 miles to join Farewell Creek at a point about one mile upstream from Lake Ontario. The average gradient of this tributary is approximately 42 feet per mile.

(e) Pringle Creek

With a drainage area of 9 square miles, Pringle Creek is the smallest of the five main drainage systems. The main branch rises in the sand plain area at the glacial Lake Iroquois shoreline about 2 miles south-east of Brooklin. It flows south through the east side of the town of Whitby and empties into the large bay at Port Whitby.

Pringle Creek falls a total of 230 feet in a distance of 7 miles with an average gradient of approximately 33 feet per mile.

Water level profiles for these main streams and a number of the smaller ones in the Authority area are shown in Figure 2.



WATER LEVEL PROFILES

SCALES AS SHOWN

DEVELOPED FROM 1/50,000 TOPOGRAPHIC SHEETS

FIG. 2.

Chalk Lake, headwaters of Lynde Creek, is typical of the many "kettle lakes" found in the Oak Ridges moraine. With a surface area of 36 acres this is the largest natural body of water within the Authority area.

Mouth of Bowmanville Creek at Port Darlington. Like all the major streams Bowmanville Creek empties into Lake Ontario through a marshy bay separated from the lake by a sand and gravel bar.

CHAPTER 2

WATER PROBLEMS

The streams and rivers of an area may be both an asset and a liability and generally speaking they are both in most parts of Ontario, including the Central Lake Ontario area. On the one hand they provide drainage, water supply, recreational facilities and sometimes navigation and power. However, periodically they will overflow their banks and cause damaging floods. Roadways and public utilities may be washed out, valuable lands eroded away and human lives threatened. Alternatively at low flow the stream may become polluted, unsightly and a menace to health. The liabilities and hardships associated with the streams can be largely eliminated if the behaviour of the streams is understood and recognized in practice.

1. Flooding

Periodic flooding has been occurring in the Central Lake Ontario area for many years and will continue to do so in the years to come. By changing the land use and opening up vast areas for agricultural and urban development, man has in general increased the rate and amount of runoff during periods of high precipitation. This has been done by reducing the amount of protective vegetative cover, by creating many acres of roof-tops and paved highways and miles of drainage ditches and storm sewers. He has also placed himself in a vulnerable position by building in the flood plains and by concentrating urban development along the streams.

As this type of development goes on more and more people are affected by the occurrence of floods, sometimes even by floods of lesser magnitude which formerly would have gone unnoticed. The toll of flood losses goes up and every once in a while a major flood occurs which creates untold havoc and misery for those involved.

View of Oshawa Creek north of No. 2 Highway. Flood plain extends from water's edge to buildings in background. No building should be permitted in such areas.

This scene on the Humber River at Weston, October 16, 1954 dramatically illustrates the foolishness of residential development on the flood plain.

Goodyear Rubber Co. dam at Bowmanville, April, 1950. Discharge capacity of the dam was seriously reduced by debris in sluiceways and flood waters overflowed the earth section of the dam in the background.

Reference is made to the accompanying list of floods obtained from local newspapers, diaries and other records. In a period of 110 years significant flooding has occurred on 23 occasions and a number of people have been drowned. It will be readily realized that this is by no means a complete list and floods of greater or lesser magnitude have undoubtedly occurred on numerous other occasions. This should be kept in mind and consideration given to the fact that as the urban development increases the problem is going to become more acute unless wise planning is implemented immediately to prevent it.

Proper land use and good conservation practices in general will aid in reducing the rate of runoff and amount of flooding. In some cases a stream channel can be enlarged or straightened to increase its capacity or control reservoirs can be constructed to hold back the flood waters. Bridges and roadways constructed across rivers and streams should be designed to handle expected peak flows and to offer as little obstruction as possible. All these aid in reducing the amount of flooding.

The toll of flood damage and injury to persons can also be reduced by the establishment and use of a flood warning system to alert the downstream areas of impending floods. The establishment of such a system should be encouraged. A further means is by controlling or restricting development of flood plains as commercial or residential areas. Most of the damage and loss of life is caused by such development. Many people fail to realize that a harmless-looking stream or drainage ditch can be converted into a raging torrent by a sudden spring thaw or summer thunderstorm.

There are a number of flood danger points in the Central Lake Ontario area and, although only the major ones have been investigated at this time, it is recommended that the Authority recognize their existence and start taking the necessary steps to bring them under control.

CHECK LIST OF FLOODS

1850-1960

(From newspaper and other historical records)

Key to streams on which floods were recorded:

B : Bowmanville Creek
F : Farewell Creek
L : Lynde Creek
O : Oshawa Creek
P : Pringle Creek

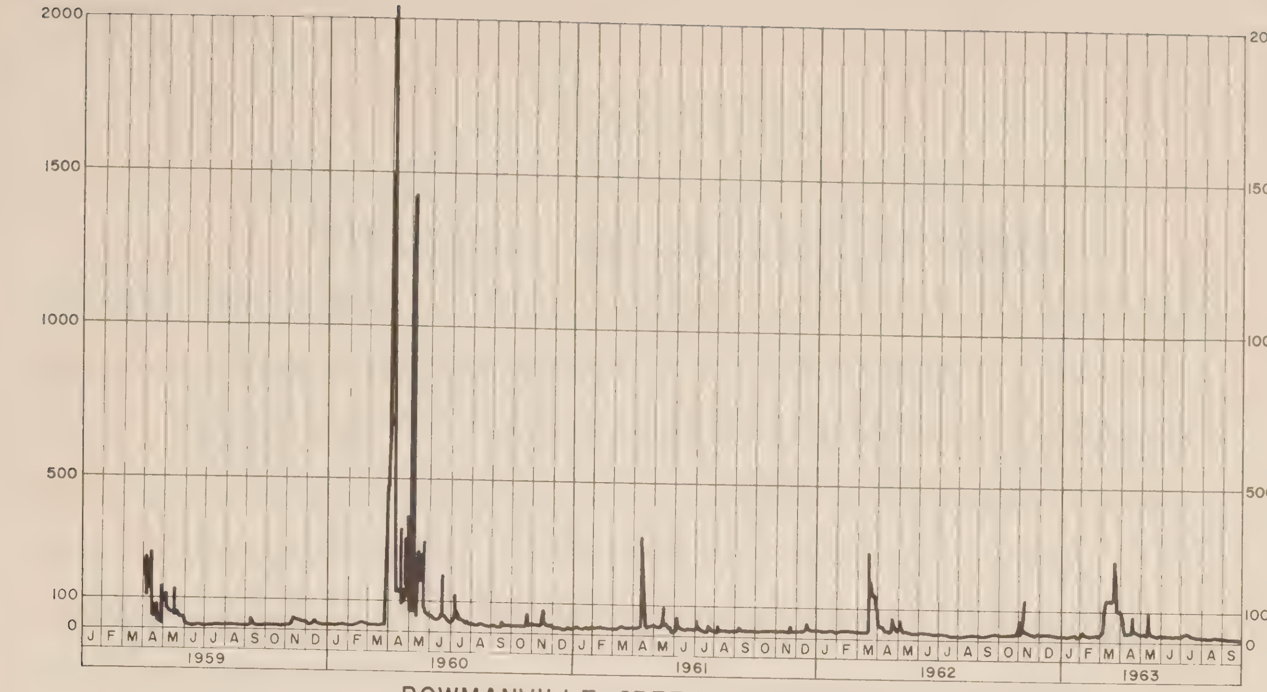
Date	Streams	Remarks
1850 April	O B L	General flooding
1857 February 16	O B L	General flooding - mills damaged at Bowmanville
1864 April	O	Man drowned on "Warrens Creek"
1875 April 1	B	General flooding
1878 February	O	Damage to Burton's Mill at Oshawa
1890 June 4, 5	O B L	Severe storm - road washouts, mills damaged
1905 March	L	Child drowns in flood
1929 April 5		General flooding - washouts, 2 people drowned, much damage
1934 March 4	O F	General flooding
1936 March		General flooding
1937 January		General flooding
June 14	F	School south of Harmony isolated by flood
1938 February 6		Streams flowing full - no damage reported
1939 April	L	Flooding vicinity of Whitby
1947 April 5, 6	O	General floods
June 2-5	O	General floods
1948 March 16	O F	General flooding
1950 March 25	O	General flooding
1951 July 16	F P	Auto plant flooded by drain backup
1952 March	O	Lowlands flooded
1953 March 4	P	Water over Dundas Street east of Whitby
1954 February	O	General flooding at Oshawa
1955 May 1	B	Vanstone's Mill pounded by ice block

2. Low Flows and Pollution

The second problem associated with the streams is that of low flow and pollution, which in many areas is as troublesome as flooding. From the available streamflow records shown in Figure 3 it may be seen that periods of low flow usually occur in June, July, August and September and occasionally in October, November and December. The average of the monthly mean flow is lowest for the period July to September with the minimum monthly flow usually occurring in August for all areas. Daily mean flows of 2, 7, 16 and 23 cubic feet per second have been recorded for the Lynde, Soper Brook, Oshawa and Bowmanville Creeks respectively during the short period of record 1959 to 1963.

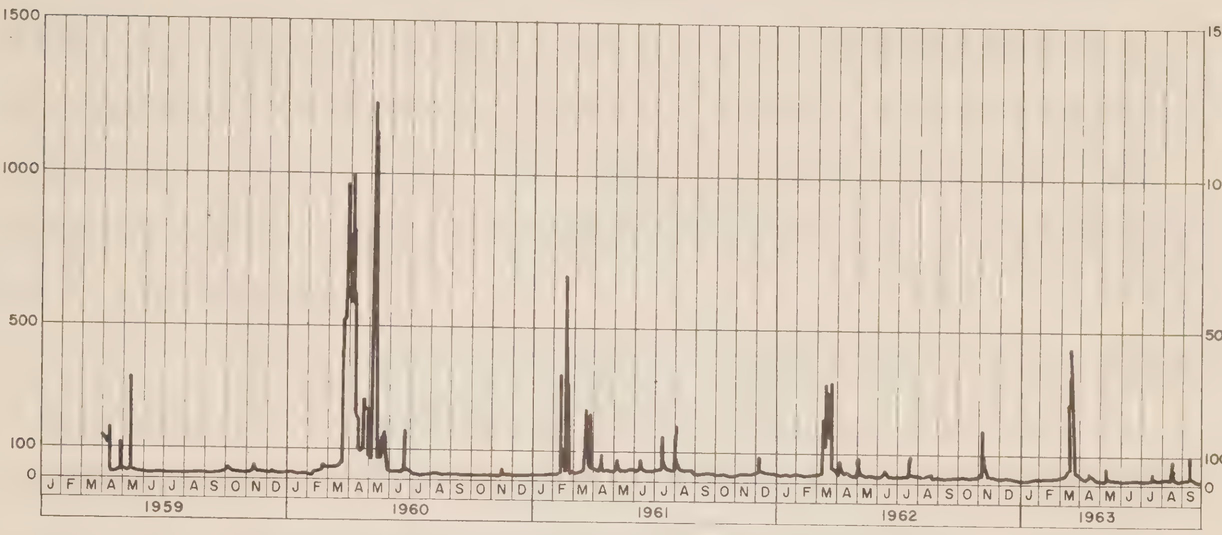
These flows apply only to the gauge sites which have comparatively large drainage areas. In all probability many of the smaller tributaries and upper reaches of the streams would be completely dried up or reduced to a mere trickle when flows of this low magnitude are recorded at the gauges. Furthermore, this low water stage usually occurs at a time when the temperatures are highest and when water is needed most. This combination of factors makes the situation more serious and the need for correcting it more apparent.

In general, water is considered to be polluted when it is unfit for a particular use. It may be polluted in respect to use as a drinking water supply and still be fit for certain recreational and industrial uses. Thus the point at which water is considered polluted is a relative one and the determination of exact standards is difficult. However, the time has come to demand that riparian water rights be observed and that all wastes should be treated before being discharged into the streams. This becomes more apparent when one realizes that at many points along the stream the quantity of sewage effluent is often equal to or greater than the natural flow.



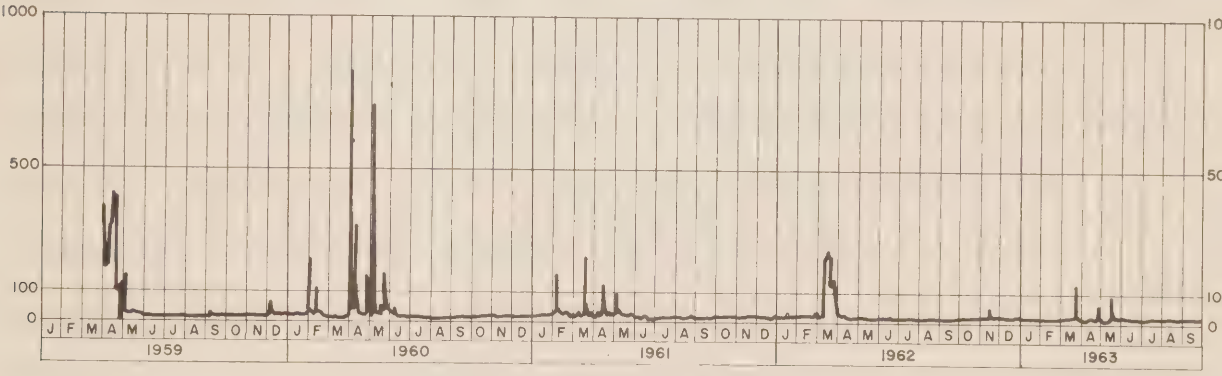
BOWMANVILLE CREEK AT BOWMANVILLE

DRAINAGE AREA = 31·2 SQ. MI.



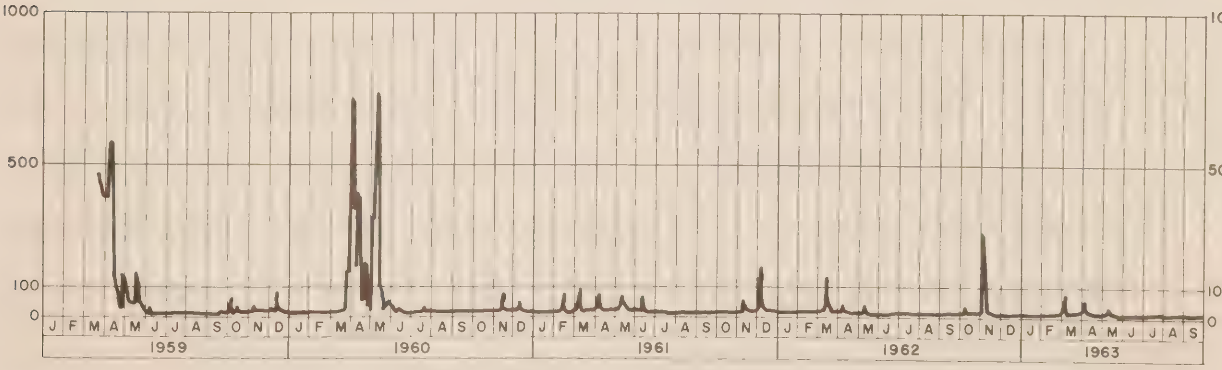
OSHAWA CREEK AT OSHAWA

DRAINAGE AREA = 38·9 SQ. MI.



LYNDE CREEK AT WHITBY

DRAINAGE AREA = 39·0 SQ. MI.



SOPER BROOK AT BOWMANVILLE

DRAINAGE AREA = 29·6 SQ. MI.

HYDROGRAPHS

MEAN DAILY FLOWS OF CENTRAL LAKE ONTARIO STREAMS

PERIOD OF RECORDS—1959–1963 · FOR LOCATION OF GAUGES SEE FIG. I

DATA PLOTTED FROM RECORDS OF THE WATER RESOURCES BRANCH, DEPT. OF NORTHERN AFFAIRS & NATIONAL RESOURCES

L. & F. Cons. Auth. Br. W. M. 1963

FIG. 3

Where the streams are being used for sewer outlet it may readily be realized how the undesirable conditions along the river are aggravated by the lack of natural streamflow. With a low water stage the stream becomes increasingly polluted, with added dangers to the health and welfare of all who would use the water. Another condition which always accompanies low flows is that pools and backwater areas form along the streams where algae and other wastes accumulate. When this occurs the water becomes stagnant and the algae and waste decay, producing foul odours and an unsightly mess. As a consequence the residents along the stream are forced to put up with this nuisance at a time when they could best enjoy the stream, and any potential recreational value the stream may have had is destroyed.

The extent and degree of pollution in the streams of the Central Lake Ontario area are covered in more detail in the Wildlife section of the conservation report and in reports published by the Ontario Water Resources Commission. In brief, the pollution in this area ranges from minor agricultural pollution on the Lynde and Bowmanville Creeks to serious industrial and domestic pollution on Harmony and Oshawa Creeks. There the population and industrial development along the streams are increasing constantly and the situation will steadily become worse unless steps are taken now to provide adequate treatment and water for the dilution of these wastes.

Although the sewage problem would be effectively remedied with the construction of treatment plants, there would still remain the problem of the poor condition of the streams during periods of low flow. Backwater areas and stagnant pools will produce growths of algae and the recreational areas in the vicinity of these will lose much of their beauty and attraction. It is felt therefore that supplemental flow during these periods would greatly benefit those who wish to use the streams and adjacent areas.

3. Soil Erosion

Another problem associated with the movement of water in a watershed is that of soil erosion. As explained in the Land section of this report, the rate of erosion depends on the particular soil, the degree and length of slope, the intensity, duration and frequency of rainfall, the velocity and duration of streamflow and the type of land use, including its effect on vegetative cover.

Although there is no one remedy or combination of remedies that can be universally applied, there are a number of basic principles of erosion control which have a widespread application. The general objectives are to

(a) Reduce the velocity of the runoff water

(b) Increase the infiltration of water

(c) Absorb the energy of raindrops.

These can be applied to each individual farm under a correct land use plan.

The most spectacular erosion in the Central Lake Ontario area, however, occurs along the stream channels where steep cut-banks are to be found at almost every bend or curve in the channel. This is well illustrated by the photograph of the Lower Gaud Damsite in Chapter 6.

This type of erosion is going on continuously but is caused chiefly by flood waters scouring the material from the bed and undermining the stream banks and valley slopes. Such erosion can become quite severe once the protecting vegetative cover on the stream banks or valley slopes is removed or the volume of water is increased by excessive runoff resulting from incorrect land use.

Mechanical methods of controlling gully and channel erosion consist of constructing small check dams on the tributaries and protecting seriously eroded stream banks by rip-rapping and permeable retards. Many of these projects can be constructed with the materials at hand, such as trees, logs, wire, boulders or brush. This program should also be

extended to protecting the roadside ditches. Less active gullies may be shaped into grassed waterways or stabilized by the planting of trees. A good sod cover should be established on the banks of road cuts and fills which are a major source of sediment in streams.

There are several recognized types of stream-bank protection with costs ranging from a few hundred dollars to several thousands of dollars, depending upon the method and materials used and the length of bank protected. Stone rip-rapping is probably the most common. Other types make use of concrete, vegetative cover, brush and wire fencing.

The construction of dams and reservoirs also helps to reduce channel erosion by controlling the stream flows. These structures would also provide flood control, summer flow and recreational benefits. Data concerning the sites investigated are given in Chapter 6.

CHAPTER 3

HYDROLOGY

Hydrology is the science which deals with the circulation of water in its various forms from the atmosphere to the earth and back to the atmosphere again. Many factors influence this movement, and particularly that portion of the cycle between the time of precipitation over land areas and subsequent runoff or direct return to the atmosphere by evaporation and transpiration.

The factors affecting this portion of the cycle are peculiar to each watershed and are difficult to evaluate without reliable recorded precipitation and streamflow data and a knowledge of the physical and other climatic characteristics of the watershed. An accurate appraisal of the data is essential for the safe and economical design of hydraulic and other works which must withstand the maximum flows the streams are capable of, and for the efficient use of the available water resources.

1. Climatic Characteristics

The climatic factors affecting runoff are extremely variable and complex. However, with sufficient data of good quality recorded over a long period of years, they can be evaluated for an area and used with a reasonable degree of confidence to predict the resultant streamflows. Observed data recorded daily will keep one informed as to existing ground and runoff conditions and with weather forecasts the people in the area may be alerted when a potential danger from runoff exists. The more important climatic factors which influence the rate and volume of runoff are the amount and intensity of rainfall, amount of snow and ice accumulation, temperature, and direction and velocity of the wind.

The average annual rainfall in the Authority area is 32.5 inches of which six inches or about 18 per cent comes in the form of snowfall. The equivalent snowfall depth is 60 inches. With an average winter temperature of 21 degrees, much

of the snow will remain on the ground until the spring break-up. This, together with the accumulation of ice in the streams and open ponds, is the chief cause of floods in this area.

While spring floods are more common, floods have occurred and may be expected in other seasons of the year, due to intense rainfall alone. The floods which followed in the wake of Hurricane Hazel, October, 1954, with extensive loss of life and property damage, are typical examples of this situation. The central path of storm "Hazel" was located approximately 45 miles west of the centre of this region, and the rainfall exceeded any previously recorded in Ontario for a storm of this duration. Being on the fringe of the storm, the rainfall amounts recorded by stations in the vicinity of the Central Lake Ontario Authority were not high. They are shown in the following table. As a matter of interest the maximum amounts recorded along the path of the storm are also shown.

TABLE 2

RAINFALL AMOUNTS FOR STORM HAZEL

OCTOBER 15-16, 1954

Station	Rainfall - Inches			
	Oct. 14	Oct. 15	Oct. 16	Total in 48 Hours
Orono	0.42	0.91	0.05	1.33
Oshawa	0.28	1.37	-	1.65
Uxbridge	0.60	3.27	0.05	3.87
Max Recorded*	1.26	7.15	-	8.41

* Recorded at Snelgrove near Brampton, Ontario.

The distribution of this rainfall over the various major watershed areas in the region resulted in the Lynde and Oshawa Creeks receiving an average depth of 2.63 inches. Bowmanville Creek and Soper Brook areas, being farther removed from the centre of the storm, received an average depth of 1.57 inches.

The maximum recorded 48-hour fall for storm Hazel was 8.41 inches. Unofficial records indicated higher amounts for local areas of up to 300 square miles and it has been calculated that rainfalls of twice these amounts could occur over areas of this size in Southern Ontario.

Thunderstorms are probably more significant in these smaller areas. Such storms are difficult to forecast and are extremely hazardous to streams with small drainage areas, which react very quickly to rainfall. A typical example is the violent thunderstorm which occurred in the Timmins area September 1, 1961. During this storm 6.7 inches of rain fell in a 12-hour period, over an area of 40 square miles. As mentioned above in the case of hurricane storms, greater amounts in shorter periods are physically possible for this type of storm also.

In this climate temperatures are also important and of course are responsible for the accumulation of water on the area in the form of ice and snow. Fortunately, the watersheds have a "southern exposure" which, to some extent, reduces the accumulation caused by the low winter temperatures.

The mean annual temperature for this region is 44 degrees while the average temperature for the winter months is 21 degrees. The average temperature for the summer months is 66 degrees, which results in high water losses through evaporation and transpiration. Direct evaporation from open water surface areas can run as high as 25 to 30 inches in this area.

Winds are of lesser importance, but do have a significant influence on evaporation. They also affect rainfall measurements, reducing the amount caught and giving readings which are too low. Adjustments of up to 35 per cent or more may be necessary, depending upon the velocity of the wind at the time of the rainfall.

2. Physical Characteristics

From the description of the watersheds as given in Chapter 1 it may be noted that the stream gradients are high. The lateral slopes are also comparatively steep, enabling the surface runoff to reach the stream channels quickly, which results in high flows. Steep stream gradients increase the velocity of the flow and at the same time the erosive power of the stream. The scarred valley slopes bear witness to this effect. Other important physical characteristics are soil types and vegetative cover.

One means of reducing the runoff from the watershed is through the use of vegetative cover. Forest cover tends to delay the snowmelt, prolonging the spring runoff and increasing infiltration. From Table 3 it will be noted that the percentage of dry wooded area in this region varies from a low of 5 per cent for the Oshawa Creek watershed to a high of 11 per cent on Pringle, Farewell and Bowmanville Creek watersheds. These are low percentages but about average for this part of Southern Ontario.

Swamp and wet scrublands vary from a low of 5 per cent in the Oshawa Creek to a high of 17 per cent in the Lynde Creek watershed. A high percentage of vegetative cover has a tendency to reduce runoff from storms of short duration and medium intensity, but its effect is negligible for intense storms of long duration.

Along with the vegetative cover, the type and condition of the soils have an important bearing on the runoff, particularly in the summer and fall months. The percentage of permeable land on the watershed, consisting of sand, gravel, and tills, varies from 5 per cent on Oshawa Creek area to 65 per cent on the Pringle Creek drainage area. These soils will act in a similar manner to the vegetation, reducing the runoff and increasing infiltration.

TABLE 3

SOIL TYPES AND WOODED AREAS - CENTRAL LAKE ONTARIO WATERSHED

SOIL TYPES	Lynde 49.7 Sq. Miles		Oshawa 45.6 Sq. Miles		Farewell 41.2 Sq. Miles		Bowmanville 64.5 Sq. Miles		Pringle 9.1 Sq. Miles	
	Area Sq. Mi.	Per-centage	Area Sq. Mi.	Per-centage	Area Sq. Mi.	Per-centage	Area Sq. Mi.	Per-centage	Area Sq. Mi.	Per-centage
Pervious										
Sands, gravels, and tills	38.9	79	38.9	85	28.4	69	51.7	80	5.9	65
Semi-Pervious										
Imperfectly drained soils and some clay lands	9.4	19	2.4	5	2.8	7	5.9	9	1.8	20
Impervious										
Poorly drained soils, some clays, and urban areas	1.4	2	4.3	10	9.9	24	6.9	11	1.4	15
WOODED AREAS	Lynde		Oshawa		Farewell		Bowmanville		Pringle	
Dry wooded and scrub land	4.0	8	2.2	5	4.4	11	6.9	11	1.0	11
Swamp and wet scrub land	8.5	17	2.5	5	5.7	14	6.0	9	0.7	8

The balance of the soils on the Lynde watershed are largely of a semi-pervious nature while those on the Oshawa and Farewell Creek watersheds are mostly impervious. The semi- and impervious soils for the Bowmanville areas are about equally divided. The areas and percentages of soil types and wooded lands for the five main watersheds are shown in Table 3.

With the physical characteristics related to their effect on runoff, the regimen of the streams becomes more clearly defined. Floods from waters running rapidly from the steep slopes of the headwater areas would be more severe and frequent were it not for the moderating effect of the wooded land and particularly the high percentage of pervious and semi-pervious soils in these areas. The wooded land retards and to some extent reduces runoff. The pervious soils reduce runoff by allowing more water to penetrate to the ground water table, where it emerges later to sustain streamflows throughout periods of low runoff.

Major and more frequent flooding can be expected on the river plains near Lake Ontario. The stream gradients in the lower part of the watersheds are generally flatter, which reduces the flow capacity of the streams and causes them to overflow their banks. Also the valleys are somewhat wider along the lake and a certain amount of encroachment has taken place. Many of the streams, however, have narrow deep valleys which have discouraged or prevented any large-scale encroachment on those areas subject to flooding.

3. Streamflow and Runoff

Streamflow and runoff consist of surface flow and ground water which enter the stream along its course and are broadly the excess of precipitation over evapotranspiration and deep seepage. Surface flow is that portion of rainfall, melted snow or ice which reaches the stream channels directly by flowing over the ground surface. Ground water flow (percolation) is going on continuously and is responsible for maintaining the flow in streams during periods of drought.

Measurement and timing of surface flow or direct runoff are of prime concern since these data are necessary for the accurate assessment of the particular problems of flood control, water supply and pollution which are of direct concern to the Conservation Authorities.

Regular observations of streamflow have been recorded for the Bowmanville, Lynde and Oshawa Creeks and for Soper Brook since April, 1959. With the exception of the Bowmanville gauge, all the gauges are manual staff or box-type gauges which are read once or twice daily. Where the reading is taken only once a day the reading is accepted as the mean for that day, which may or may not be true. Similarly with twice daily readings, the average is taken as the mean. Since the flow in these streams can vary considerably in a matter of a few hours, the flow records can be greatly in error and must be used with caution. The Bowmanville Creek gauge was converted to a recording type in 1961 but the records have not been satisfactory and it may be necessary to stabilize the control section or move the station.

The location of the gauges in the Central Lake Ontario area is shown in Figure 7 and the hydrographs for the mean daily flows are shown in Figure 3. The maximum flow recorded during the periods of record and corresponding estimated peak flow for each of the gauges are given in the following Table 4.

TABLE 4

MAXIMUM MEAN DAILY AND ESTIMATED PEAK FLOW

Gauge	Date	Drainage Area Sq. Mi.	Flow in Cu. Ft. per Sec.	
			Mean Daily Recorded	Peak Estimated
Bowmanville	April 4,1960	31.2	2,030	3,635
Soper	May 9,1960	29.6	743	1,550
Lynde	April 2,1960	39.2	818	1,465
Oshawa	May 9,1960	38.9	1,210	1,830

Streamflow records are not of sufficient length to permit a reliable analysis of the runoff. However, from these few records it is evident that the excessive runoff occurs most frequently during the spring break-up.

4. Design Flows

The design flow is that flow which is adopted as the basis for the design of a river control structure or a flood control plan. For design purposes there are three standards which are generally accepted, depending upon the degree of protection required or warranted and the consequences should this design flow be exceeded. These are:

(a) The area flood is the most frequently occurring flood of sufficient magnitude to cause significant damage.

(b) The regional flood is that which would result if the greatest recorded storm in the region were transposed to the watershed under study. For this area and most of Southern Ontario, the regional storm would be of the magnitude of Hurricane Hazel as it occurred over the Humber watershed in October, 1954.

(c) The probable maximum flood is defined as a flood resulting from the probable maximum rainfall.

The design flow which is generally accepted for flood protection and flood plain zoning in Southern Ontario is that which would result from a storm of the magnitude of Hurricane Hazel centred over the watershed.

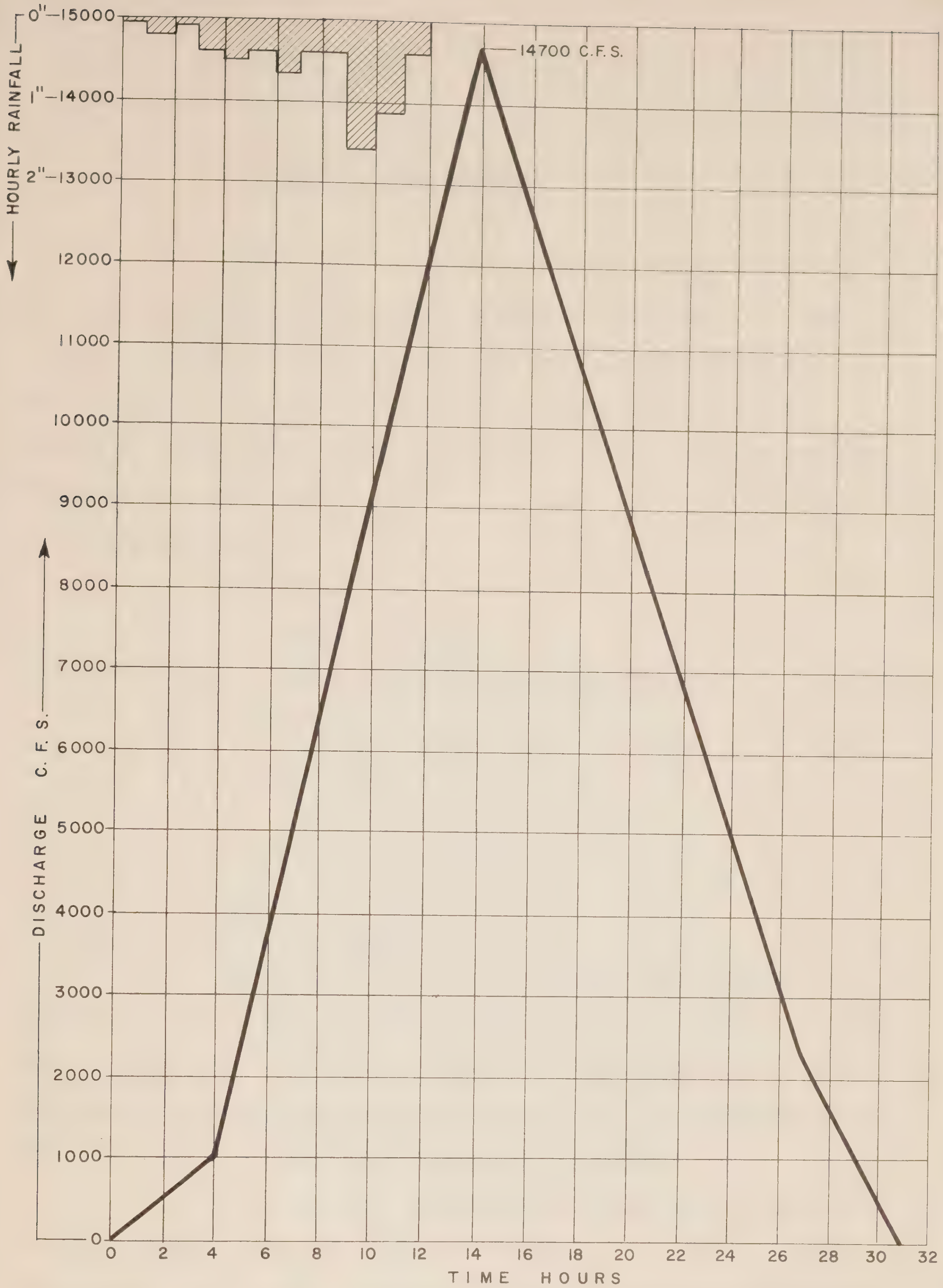
Due to the lack of sufficient flow records for the streams in the Central Lake Ontario area, it was necessary to resort to a synthetic hydrograph to determine a design flow value. For this purpose the mean daily flow records for the Soper Brook gauge from the May 7-9, 1960, storm were used. These were correlated with the records from the recording gauge on the adjacent Duffin Creek and a tentative 4-hour unit hydrograph derived for Soper Brook. On the basis of area adjustment similar hydrographs were prepared for each of the other streams.

The peak flows for the 4-hour unit hydrographs, together with the peak discharges for the streams, are shown in the following Table 5. Figure 4 shows the design flood hydrograph for Oshawa Creek, which is typical for the Central Lake Ontario region.

TABLE 5

FOUR-HOUR UNIT GRAPH PEAKS

Stream	Drainage Area Sq. Miles	Unit Peak c.f.s.	Unit Rate c.s.m.
Soper	30	1,900	64
Oshawa	40	2,180	56
Farewell	24	1,830	77
Bowmanville	31	1,950	62
Lynde	39	1,980	51



DESIGN-FLOOD HYDROGRAPH
· OSHAWA CREEK ·

BASED ON A 12 HOUR STORM OF THE INTENSITY OF HURRICANE HAZEL AS CENTRED OVER THE HUMBER WATERSHED.

DISCHARGE CALCULATED AT THE MOUTH OF OSHAWA CREEK — DRAINAGE AREA 39 SQ. MI.

L.&F. Cons. Auth. Br. W.M. 1963

FIG. 4

CHAPTER 4

FLOOD CONTROL METHODS

Flood control as referred to in this report is not meant to imply complete and guaranteed protection for all time to come but instead a practical degree of protection to minimize flood damage and ensure, as far as possible, the safety of human lives. Effective flood control is a problem of land use and water regulation and includes one or all of the following methods:

1. Proper land use practices
2. Reforestation
3. Channel improvements and diversions
4. Diking
5. Reservoirs
6. Zoning
7. Flood warning system

1. Proper Land Use Practices

These have to do with such farming methods as tend to reduce surface runoff and soil erosion. Important among these are contour ploughing, restricted crop rotation, diversion terraces and grassed waterways, all of which serve to delay the surface runoff and promote infiltration.

Land use practices provide effective control for small watersheds and for the headwater areas of large watersheds, but in most cases such measures must be supplemented by other hydraulic works such as dams and channel improvements.

2. Reforestation

The reforestation of marginal and sub-marginal land has an ameliorating effect on runoff and checks erosion on steep as well as moderate slopes. The effect of forest cover in delaying snowmelt prolongs the runoff from this source and substantially reduces the damaging peak flows. The Central

Lake Ontario watershed are unfortunate in this respect, having less than 10 per cent of the entire land area of the watersheds under forest cover.

3. Channel Improvements and Diversions

Channel improvements include widening, straightening, deepening and regrading the river channel through, and often for some distance below, the trouble area. In many cases these works increase the stream velocity and it is necessary to protect the banks from erosion or provide drop structures to reduce the velocity. Depending upon the channel slopes and flow velocities encountered the channel may be grassed, lined with concrete or gabions, or rip-rapped.

Where the topography is suitable it is sometimes possible to divert a stream or river around the flooded area or to another watershed. This involves creating an entirely new channel which would require the precautions indicated above for channel improvements. Diverting water to another watershed must be considered carefully in order to avoid the possibility of creating or aggravating a flood problem in that watershed.

4. Diking

Dikes are embankments usually constructed of earth fill with an impervious clay core. Located at or near a river, they seal off the flooded area and confine the flood flows to the river channel but tend to increase the flood heights. If the velocity is low and there is no danger of ice scour, the slopes may be protected by sodding. Otherwise it is necessary to face the river side with stone rip-rap or concrete. Often it is also necessary to install pumps to handle the drainage from the local area behind the dikes.

Dikes must be provided with ample freeboard, substantially built and maintained in good condition, for if they should be topped or breached the damage could be greater than if they had not been there.

Abandoned dam on Oshawa Creek above King Street. Dam is slowly disintegrating filling the channel with debris.

Remains of old bridge on Oshawa Creek near Thomas Street. This abandoned bridge will tend to restrict flood flows and cause higher water levels upstream.

Dense shrub growth in channel at this bridge on Oshawa Creek impedes the free passage of flood flows. There are many similar sections of channel which could be cleared to advantage.

5. Reservoirs

With adequate storage provided in a system of reservoirs, a sufficient volume of the flood waters may be impounded and controlled to the extent that the flood crests will be lowered to a safe stage at the places subject to flooding. Unlike the other control measures, which are designed to get rid of the excess water as quickly as possible, reservoirs conserve the excess water for periods of low flow. They also provide lakes for recreation, help maintain the ground water table and enhance the river generally by maintaining the flow.

A number of potential reservoir sites were investigated in the Central Lake Ontario area. The sites have been noted for consideration and are described in some detail in Chapter 6.

6. Zoning

As mentioned previously, flood problems are created by the foolish use of those lands which in truth belong to the river. It would be impractical in most cases to prevent the use of these lands entirely, as substantial benefits may be derived by developing them for uses compatible with the periodical inundation. By an adjustment in the use of flood plains, however, much of the suffering and damage brought on by floods can be eliminated.

One method for making this adjustment is by "flood plain" zoning. Municipalities have the power to regulate the use of lands subject to flooding under Section 30 of The Planning Act, and the Conservation Authorities have the power, under The Conservation Authorities Act, to pass regulations which would restrict any development that would obstruct the safe passage of flood flows.

Zoning is the most practical way of obtaining the required flood protection in the area under study and extensive flood plain zoning has been recommended for the

Central Lake Ontario area. The following chapter deals with this in greater detail.

7. Flood Warning System

An adequate and reliable flood warning system is a vital part of any flood control work. With such a service available, those living in flood-vulnerable areas may be alerted and precautions taken to minimize the damage that results from any overflow.

The Conservation Authorities Branch, through its hydrometeorologist seconded from the Meteorological Branch, Department of Transport, Canada, is responsible for issuing flood warnings. This program is seriously handicapped by the lack of basic hydrologic data and observation stations. However, the network of rainfall and streamflow gauges and snow survey courses is being expanded and improved and the continuing flow of basic data from these gauges will provide the information necessary to make this service more effective. Flash floods on small watersheds are difficult to forecast and a close watch for excessive rainfall on individual areas is required to give advance warning of this type of flooding.

CHAPTER 5

ZONING AND REGULATIONS

1. General

The rapid growth of our cities, towns and villages in the past half century has placed a premium on land it was formerly considered unwise and uneconomical to build upon. People have forgotten that rivers have flood plains and that they will continue to form these plains, over which the water will flow when the capacity of the normal channel is exceeded. This fact was noted in an article published in the "Engineering News Record" almost 25 years ago:

> "Rivers were here long before man and for untold ages every stream has periodically exercised its right to expand when carrying more than normal flow. Man's error has not been in the neglect of flood control measures but his refusal to recognize the right of rivers to the floodway."

People have failed to recognize the fact that the flood plain is in truth part of the channel to be used whenever the flow exceeds the capacity of the normal or low-water portion of the channel. Artificial channels are constructed in this way, as is illustrated by the Brampton flood control channel and the channel improvement work being carried out on Black Creek by the Metropolitan Toronto and Region Conservation Authority. In each case, a small channel is constructed within a larger one to carry the normal summer flows. The larger channel remains dry except in times of flood when it will be used to capacity.

In natural valleys the areas into which the river will expand in times of flood are defined as

(a) Flood plains - the lands adjoining a river or stream which have been or may be hereafter inundated;

(b) Floodways - the channel and that portion of the overbank area which is required to carry flood waters effectively.

In some cases, depending upon the terrain and magnitude of the design storm, these two zones may be synonymous, but normally the flood plain will be a wider area embracing the floodway. Usually it is not practical to provide sufficient control to reduce all flood flows to the capacity of the normal flow channel and, therefore, provision must be made to accommodate some overbank flow. The Metropolitan Toronto and Region Conservation Authority has an extensive flood plain acquisition program under way and in fact almost one-third of the cost of its $40 million Flood Control Plan will be spent on acquiring flood-vulnerable land. The extent of damage and loss of life in the flood following Hurricane Hazel in October, 1954, and the shortage of economical storage sites on the watersheds under its jurisdiction made this plan mandatory. However, much of this expense and the difficulty in acquiring these lands could have been avoided by the timely passing of zoning by-laws which would have restricted the development of the flood plain lands to agriculture, recreation or similar compatible uses.

For a municipality to achieve the most benefit from a flood plain zoning scheme, the plan must be adopted at an early stage in its development. For many areas in Ontario, such as the Central Lake Ontario area, this planning should be done now in order to prepare for the rapid population growth and decentralization of industry. However, the lack of basic data and maps to define the flood problem and to delineate the specific areas subject to flooding is a major handicap to initiating such a scheme. Some areas, such as Darlington Township, have the flood plains zoned as greenbelt areas. Other municipalities have labelled the flood plains "open spaces" and "park lands". These designations are at the best temporary unless the municipality is prepared to purchase and maintain the lands as such.

Once the floodway and flood plain are delineated on official plans based on flood records, there would be little chance of anyone obtaining approval to proceed with any unwise

development in the flood-vulnerable areas. White* in his study of flood problems of the U.S.A. has recommended that the flood plain be divided into three zones: prohibitive, restrictive and warning. In any case the first prerequisite for zoning flood plains is to determine the degree of flood protection to be provided and to outline the areas that would be affected.

The water levels for the Hazel flood are available for many streams in this area, and these stages as they occurred on the Humber River and Etobicoke Creek are considered to be adequate for these respective watersheds. However, Hazel floods as they occurred in other areas or the highest flood of record, may not necessarily be adequate for the particular watershed under study. It must be recognized that in most areas greater floods can, and probably will, occur. Therefore, design floods based on transposed storms of greater magnitude should be used to determine the extent of the flood plains for these areas.

As has been indicated in the chapter on hydrology, there have been, until recently, no adequate rainfall and stream flow data collected for floods in the area. For this reason, it is necessary to undertake studies of all regional storms which are transposable to the Central Lake Ontario area which could produce floods greater than any presently recorded.

An article in "Fortune" magazine, telling of the flood damage in the Nantucket River Valley of West Central Connecticut following Hurricane Diane in 1955, lamented:

"They had prepared for the future in terms of the past and when the future arrived on August 18 and 19, it so far exceeded expectations as to render all preparations futile."

2. Flood Plain Mapping

As mentioned previously, the flood that would result from a storm of the magnitude of Hurricane Hazel has

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* White, F. Papers on Flood Problems, University of Chicago, Department of Geography, Research Paper No. 70.

generally been accepted as the design flood. Having selected the storm, its pattern is then transposed to the watershed under study and the resultant flows are determined. The peak or highest flow thus obtained is used for the protection system whether it be dam and reservoirs, channel improvements, zoning or a combination of all three.

For the purpose of mapping the flood plain, three methods, depending on the data available, have been used. The first method is exemplified by the work carried out by the Metropolitan Toronto and Region Conservation Authority. In this case, suitable contour maps of the river valleys systems were made from aerial photographs and the flood lines marked thereon from high water marks established in the field immediately following flood Hazel. A second flood line, based on a design flood determined by centering storm Hazel over the area, was added to the maps for those areas which did not receive the full force of Hazel.

The second method deals with the use of existing topographical mapping and is illustrated by the accompanying flood line sheets prepared for Oshawa Creek. Here a design flood derived by applying storm Hazel to the watershed was used for the flood line calculations. Having determined the peak flow, a flood line profile was then prepared, using cross-sections taken from the topographical mapping along with other field data such as measurement of bridge openings. The elevation or depth of the flood waters above the bed of the stream was obtained from this flood profile at known points and transferred to the contour maps. The flood lines were then added by assuming a uniform water surface slope between the points and drawing the line between them.

For those municipalities where no suitable mapping exists and funds are not available for the preparation of large-scale maps, a third method of mapping may be used. This involves the use of existing aerial photography and valley

cross-sections and stream bed elevations obtained from field surveys. A flood line profile is prepared as described above and the elevations from the profile are then transferred directly to the aerial photographs. This was done for a number of municipalities on Farewell, Black and Bowmanville Creeks as indicated on the watershed map, Figure 1.

For those areas designated as greenbelt on the township of Darlington zoning plan, the flood plains were outlined on aerial photographs. An example of this type of mapping is shown on the accompanying photograph of Bowmanville Creek at Hampton. In contrast to marking the flood line on the photographs in the field by point identification, photogrammetric methods and high water marks can be employed to transfer the flood line elevations to the photographs. The Whitson River flood plain lands were outlined in this manner for the Whitson Valley Conservation Authority. The river was cross-sectioned at suitable intervals and, from high water marks obtained from the most adequately recorded flood, a flood line profile was prepared. Using this profile and higher water stage elevations for a regional type storm, the area that would be affected by a flood of this magnitude was outlined on the photographs by stereo-projection.

All three methods are similar. A recorded flood or design flood is selected. A flood line profile is constructed using data obtained from either field surveys or topographical maps, and the flood elevations are transferred to a contour map or aerial photograph. The last two methods are practical only for the smaller communities and towns with localized flood problems. For the larger, more densely populated areas, such as the City of Oshawa, the first method, using available contour mapping and aerial photography, is necessary to ensure sufficient accuracy. In addition to defining the flood plain land, the topographical mapping is essential for the proper planning of a community, laying out subdivisions,


FLOOD PLAINS
OF BOWMANVILLE CREEK
AT HAMPTON
ONTARIO DEPARTMENT OF LANDS AND FORESTS
CONSERVATION AUTHORITIES BRANCH
1962
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200 0 200 400 600 800 1000

roadways, water and sewer systems, and is justified for these reasons alone.

The development within the Central Lake Ontario Authority area is currently at the stage where immediate action should be taken to outline the flood-vulnerable areas, and to prevent any building-up which would preclude the acquisition of these areas and make it necessary to undertake other more costly flood control work. After classifying the land in terms of risk, the next step is to establish standards of flood plain use. The final and possibly the most important step is the rigid enforcement of these standards. Because of the number of subdivisions going in and suburban development around Oshawa, a zoning scheme for Oshawa Creek and its tributaries is urgently needed. Flood plain maps have been prepared for Oshawa Creek as far north as the airport and these, with possibly some minor adjustments, could be used for this purpose.

3. <u>Zoning By-Law</u>

To assist the Authority and member municipalities further in this regard, a copy of a typical flood plain zoning by-law is shown below.

TOWNSHIP OF ETOBICOKE
BY-LAW NO. 11,757
A BY-LAW TO PROHIBIT THE ERECTION
OF BUILDINGS AND STRUCTURES FOR
RESIDENTIAL OR COMMERCIAL PURPOSES
IN PART OF THE TOWNSHIP OF ETOBICOKE

WHEREAS aerial photographs have been taken showing the high water line reached by the waters of the Humber River and its branches in October 1954 and, from which photographs, contour maps have been compiled showing such line as a dotted line thereon, copies of which maps are attached to and form part of this by-law;

AND WHEREAS such high water line varies considerably in its location and it is deemed desirable to more accurately define the line of reference to contour lines for the purpose of this by-law;

AND WHEREAS it is deemed expedient to prohibit the erection of buildings and structures for residential or commercial purposes in that part of the Township of Etobicoke lying within the bed of the Humber River and its branches, and lying between the the red lines marked on the said maps and the normal bed of the Humber River and its branches, by reason of the fact that such land is subject to flooding.

NOW THEREFORE, THE MUNICIPAL COUNCIL OF THE CORPORATION OF THE TOWNSHIP OF ETOBICOKE ENACTS as follows:-

1. No person shall erect any building or structure for residential or commercial purposes in that part of the township of Etobicoke lying in the bed of the Humber River and any of its branches, and between the red lines as designated on the maps attached hereto, and the normal bed of the Humber River and its branches, provided, however, that this by-law shall not operate to prohibit the erection of buildings and structures designated to be used in connection with the use of the said lands for parks or recreational purposes.

2. This By-law shall not apply to any building or structure which, on the day of passing of the By-law, is erected on the said lands, nor shall the By-law apply to any building or structure the plans for which have, prior to the day of the passing of the By-law, been approved by the Building Commissioner so long as the building or structure, when erected, is used for the purpose for which it was erected.

3. Any person convicted of a breach of any of the provisions of this By-law shall forfeit and pay, in the discretion of the Convicting Magistrate, a penalty not exceeding the sum of Three Hundred Dollars ($300.00) exclusive of costs for each offence, and every such penalty shall be recoverable under The Summary Convictions Act.

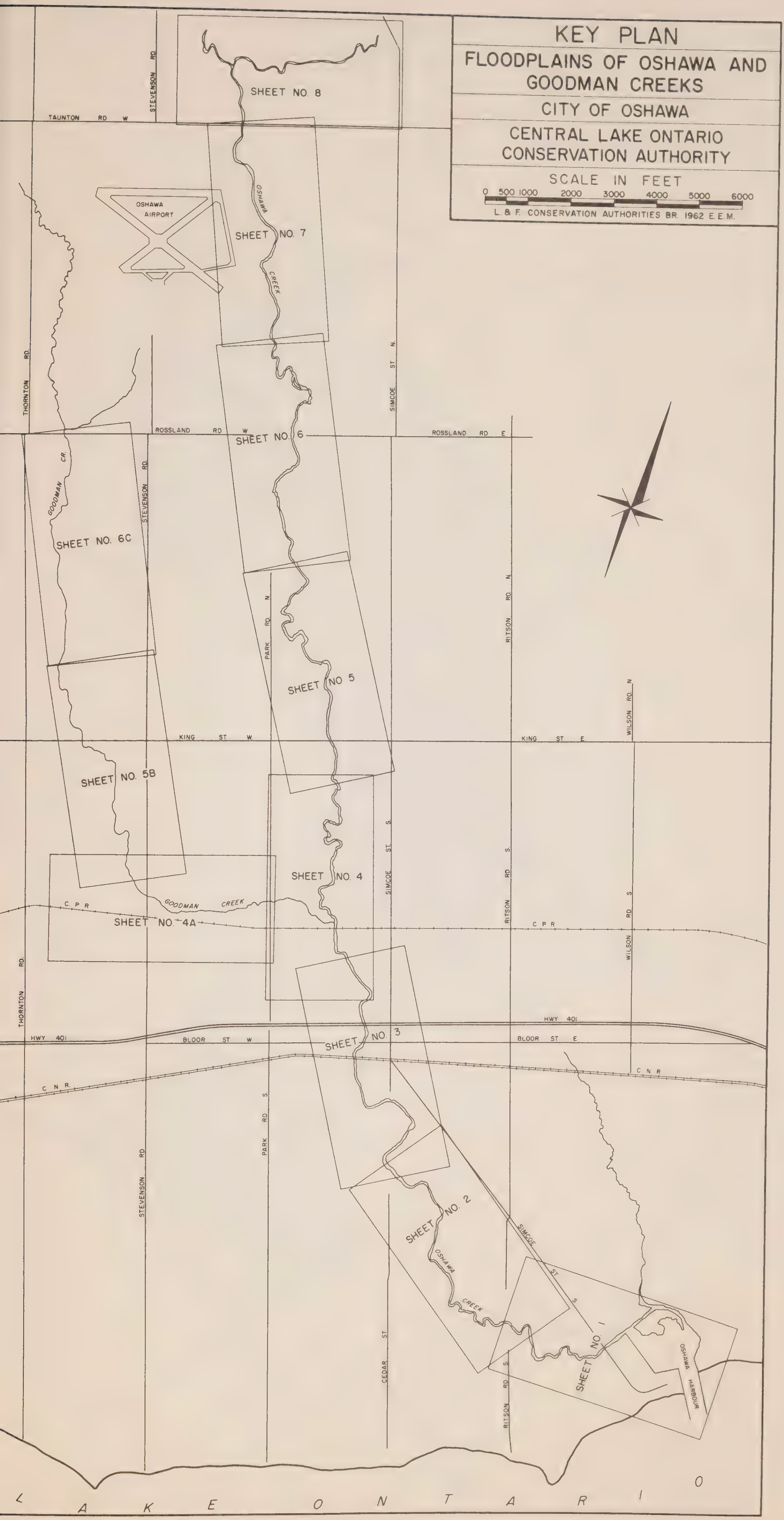
4. The provisions of Clause 3 shall be in addition to any other remedy which the Corporation of the Township of Etobicoke or a ratepayer thereof may have to restrain by action a contravention of this By-law.

5. Subject to the approval of The Ontario Municipal Board, this By-law shall come into force and take effect upon the date hereof.

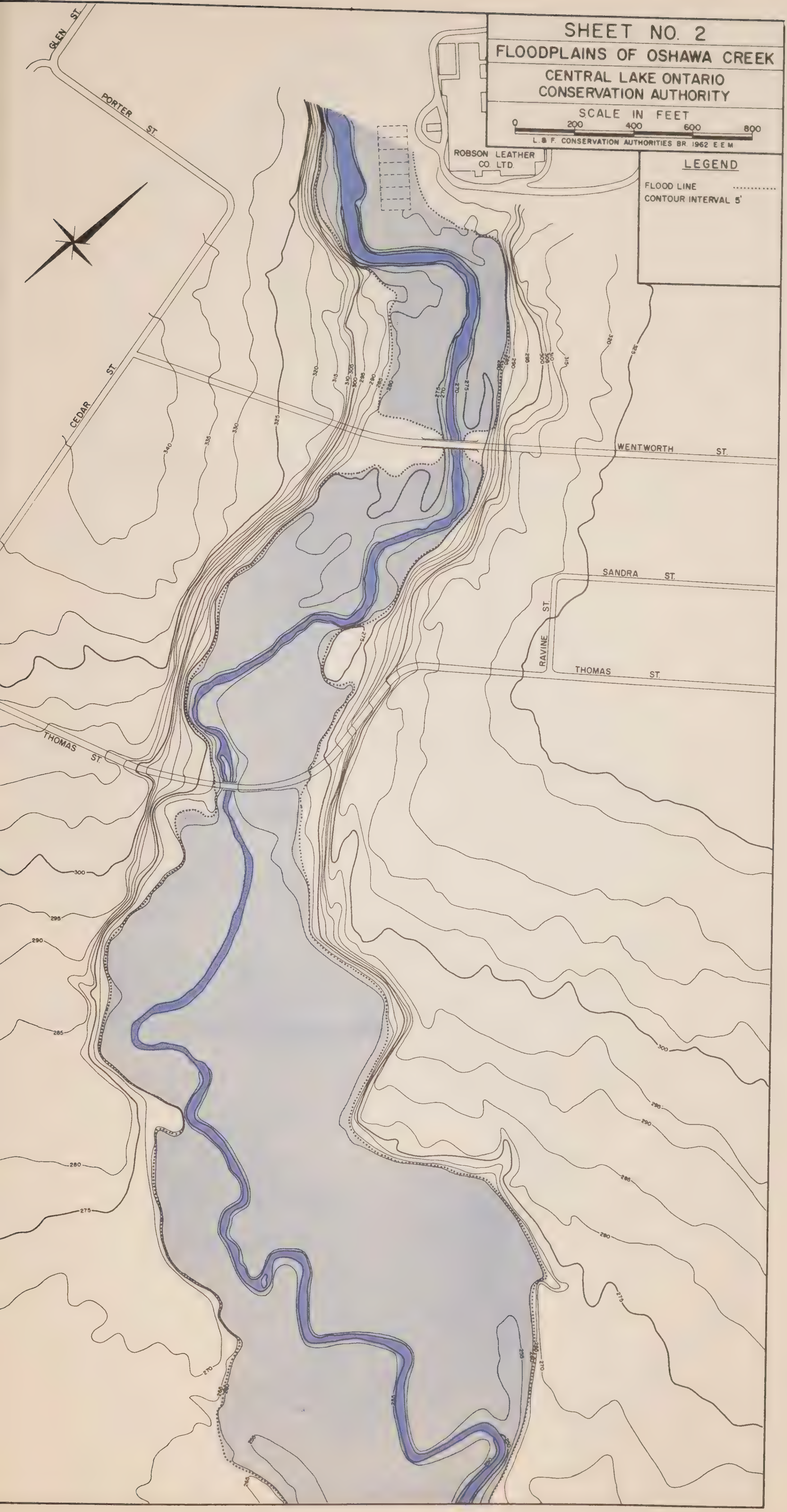
READ a first, second and third time and passed in Council this 5th day of November, A.D. 1956.

W. B. LEWIS
Reeve
S. W. Eckersley
Clerk

It should be emphasized that with better flow records, flood plains are more accurately defined. Future mapping could be done in the Township of Whitby and the Township of Darlington to complement and reinforce the existing zoning by-laws.


KEY PLAN
FLOODPLAINS OF OSHAWA AND GOODMAN CREEKS
CITY OF OSHAWA
CENTRAL LAKE ONTARIO CONSERVATION AUTHORITY
SCALE IN FEET
0 500 1000 2000 3000 4000 5000 6000
L. & F. CONSERVATION AUTHORITIES BR. 1962 E.E.M.
SHEET NO. 8
SHEET NO. 7
SHEET NO. 6
SHEET NO. 6C
SHEET NO. 5
SHEET NO. 5B
SHEET NO. 4
SHEET NO. 4A
SHEET NO. 3
SHEET NO. 2
SHEET NO. 1
OSHAWA AIRPORT
OSHAWA CREEK
GOODMAN CR.
GOODMAN CREEK
TAUNTON RD W
STEVENSON RD
THORNTON RD.
ROSSLAND RD W
ROSSLAND RD E
SIMCOE ST N.
SIMCOE ST S.
PARK RD N
PARK RD S.
RITSON RD N
RITSON RD S.
WILSON RD N
WILSON RD S
KING ST W.
KING ST E.
C.P.R.
HWY 401
BLOOR ST W
BLOOR ST E
C.N.R.
CEDAR ST
OSHAWA HARBOUR
LAKE ONTARIO


LEGEND
FLOOD LINE
CONTOUR INTERVAL 5'
SHEET NO. 1
FLOODPLAINS OF OSHAWA CREEK
CENTRAL LAKE ONTARIO
CONSERVATION AUTHORITY
SCALE IN FEET
0 200 400 600 800
L. & F. CONSERVATION AUTHORITIES BR. 1962 E.E.M.
HARBOUR RD.
SIMCOE ST.
TANKS
LAKEVIEW PARK AVE.
HENRY ST.
OSHAWA HARBOUR
LAKE ONTARIO
255
260
250



SHEET NO. 2
FLOODPLAINS OF OSHAWA CREEK
CENTRAL LAKE ONTARIO CONSERVATION AUTHORITY
SCALE IN FEET
0
200
400
600
800
L. & F. CONSERVATION AUTHORITIES BR. 1962 E.E.M.
LEGEND
FLOOD LINE
CONTOUR INTERVAL 5'
ROBSON LEATHER CO. LTD.
GLEN ST.
PORTER ST.
CEDAR ST.
WENTWORTH ST.
SANDRA ST.
RAVINE ST.
THOMAS ST.
THOMAS ST.

SHEET NO. 3
FLOODPLAINS OF OSHAWA CREEK
CENTRAL LAKE ONTARIO
CONSERVATION AUTHORITY
SCALE IN FEET
0 200 400 600 800
L & F. CONSERVATION AUTHORITIES BR. 1962 E.E.M.
LEGEND
FLOOD LINE
CONTOUR INTERVAL 5'
MILL ST
MILL ST.
OXFORD ST.
COLLEGE AVE.
DUAL LANE HIGHWAY 401
JACKSON ST.
SIMCOE ST. S.
BLOOR ST. W.
BLOOR ST. E.
C. N. R.
KNIGHTS RD.
CEDAR ST.
ERIE ST.
ANNIS ST.
ALBERT ST.
PHILLIPS ST.
CONANT ST.
SIMCOE ST. S.
MALAGA RD.
GORDON ST.
WHITING AVE.
ROBSON ST.
FRANK ST.
GLEN ST.
ROBSON LEATHER
CO. LTD.

LEGEND

FLOOD LINE ....
CONTOUR INTERVAL 5'

SHEET NO. 4

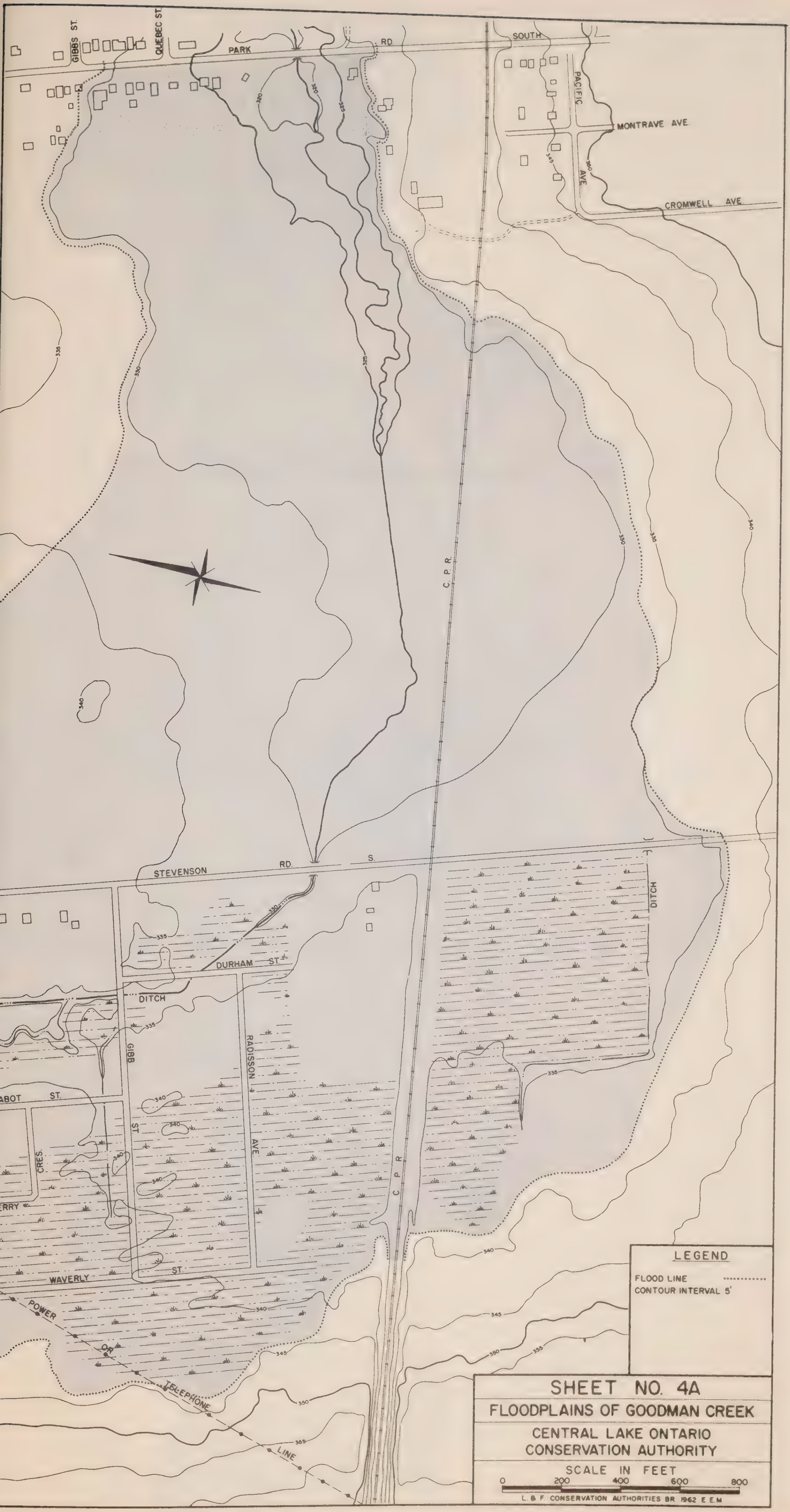
FLOODPLAINS OF OSHAWA AND GOODMAN CREEKS

CENTRAL LAKE ONTARIO CONSERVATION AUTHORITY

SCALE IN FEET

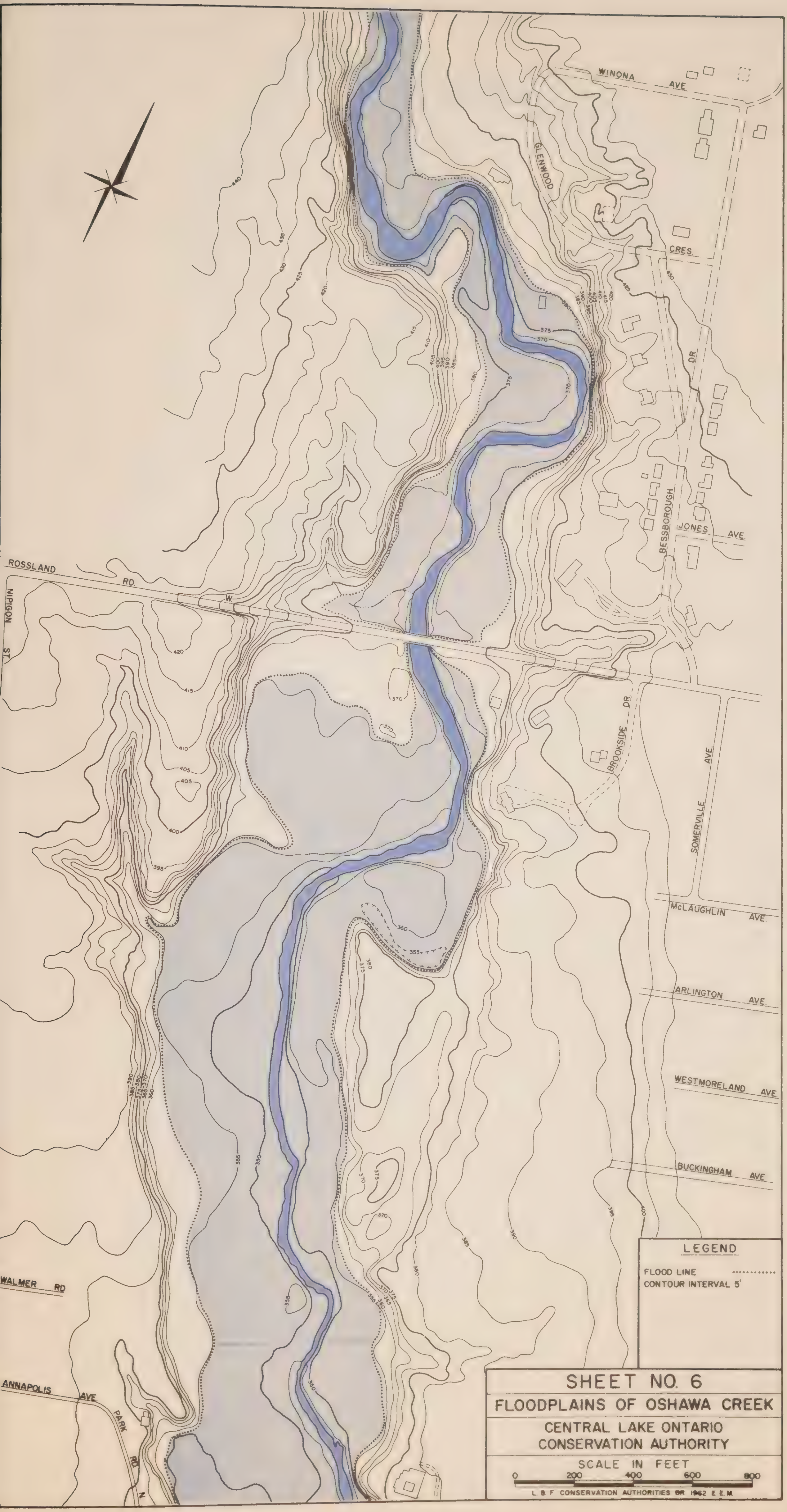
0 200 400 600 800

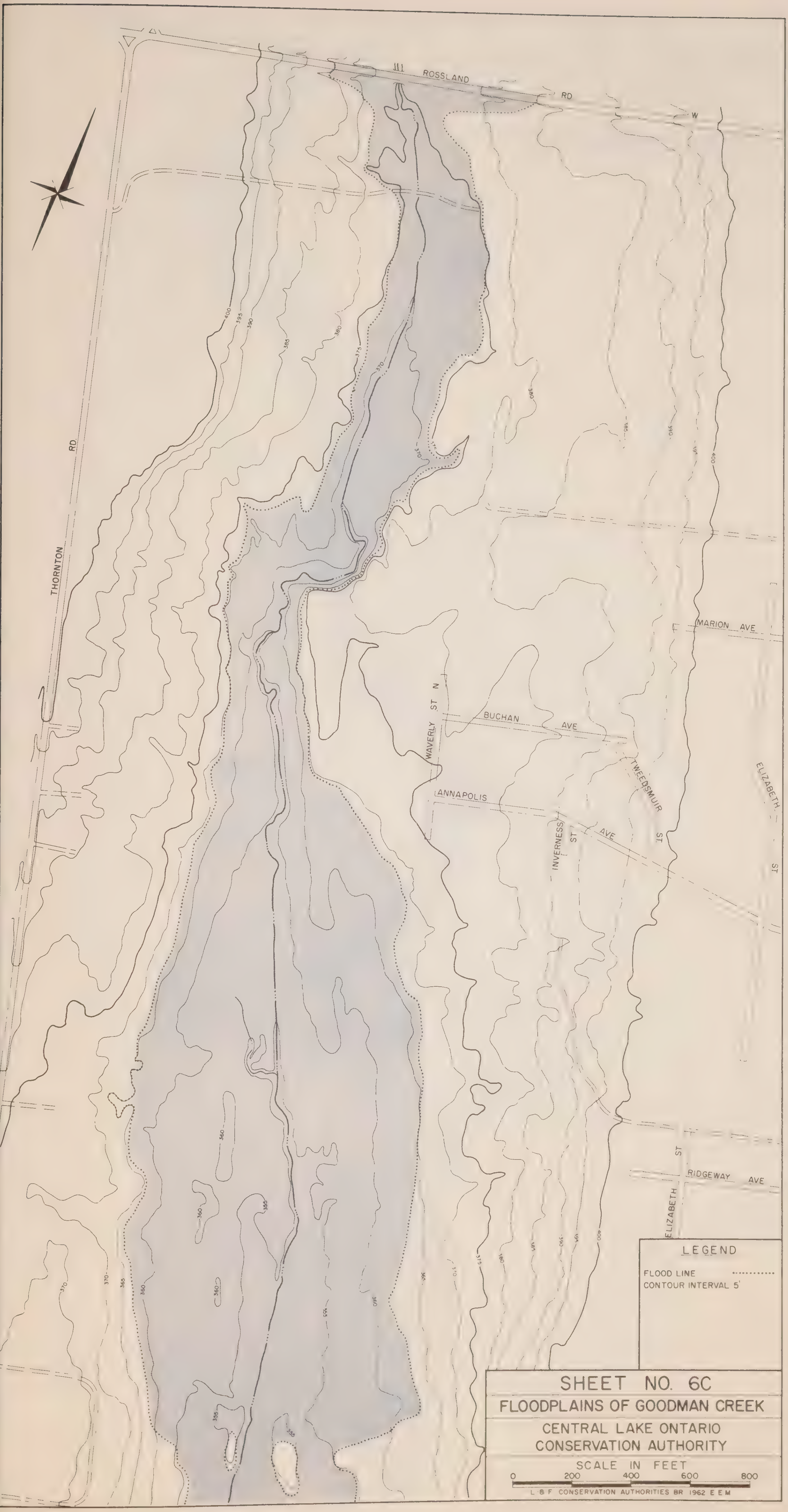
L. & F. CONSERVATION AUTHORITIES BR. 1962 E.E.M.


GIBBS ST.
QUEBEC ST.
PARK
RD.
SOUTH
PACIFIC
AVE.
MONTRAVE AVE.
CROMWELL AVE.
C. P. R.
STEVENSON
RD.
S.
DITCH
DURHAM ST.
DITCH
GIBB
ST.
RADISSON
AVE.
ABOT ST.
CRES.
ERRY
WAVERLY
ST.
POWER
OR
TELEPHONE
LINE
C P R
LEGEND
FLOOD LINE
CONTOUR INTERVAL 5'
SHEET NO. 4A
FLOODPLAINS OF GOODMAN CREEK
CENTRAL LAKE ONTARIO
CONSERVATION AUTHORITY
SCALE IN FEET
0
200
400
600
800
L. & F. CONSERVATION AUTHORITIES BR. 1962 E.E.M.


SHEET NO. 5
FLOODPLAINS OF OSHAWA CREEK
CENTRAL LAKE ONTARIO CONSERVATION AUTHORITY
SCALE IN FEET
0 200 400 600 800
L.B.F. CONSERVATION AUTHORITIES BR 1962 E.E.M.
LEGEND
FLOOD LINE
CONTOUR INTERVAL 5'
PARK ROAD NORTH
PARK RD N
ALEXANDRA ST
ALMA ST
GROOMS AVE
FREDERIC ST
LOUISA ST
ELGIN ST. W
McMILLAN DR
ARENA ST
COLBORNE ST. W
WARREN AVE
PUNSHON AVE
GLADSTONE AVE
RINK
KINSMEN STADIUM
ARENA
BOND ST
KING ST W


SHEET NO. 5B
FLOODPLAINS OF GOODMAN CREEK
CENTRAL LAKE ONTARIO
CONSERVATION AUTHORITY
SCALE IN FEET
0 200 400 600 800
L. & F. CONSERVATION AUTHORITIES BR 1962 E.E.M.
LEGEND
FLOOD LINE
CONTOUR INTERVAL 5'
KING ST. W
CABOT ST
MONTCALM AVE.
WAVERLY ST.
HARLOW COURT
HEALY COURT
CARTIER ST
PERRY CRESENT
POWER OR TELEPHONE LINE
TALON COURT
TALBOT COURT
DURHAM ST
STEVENSON RD S

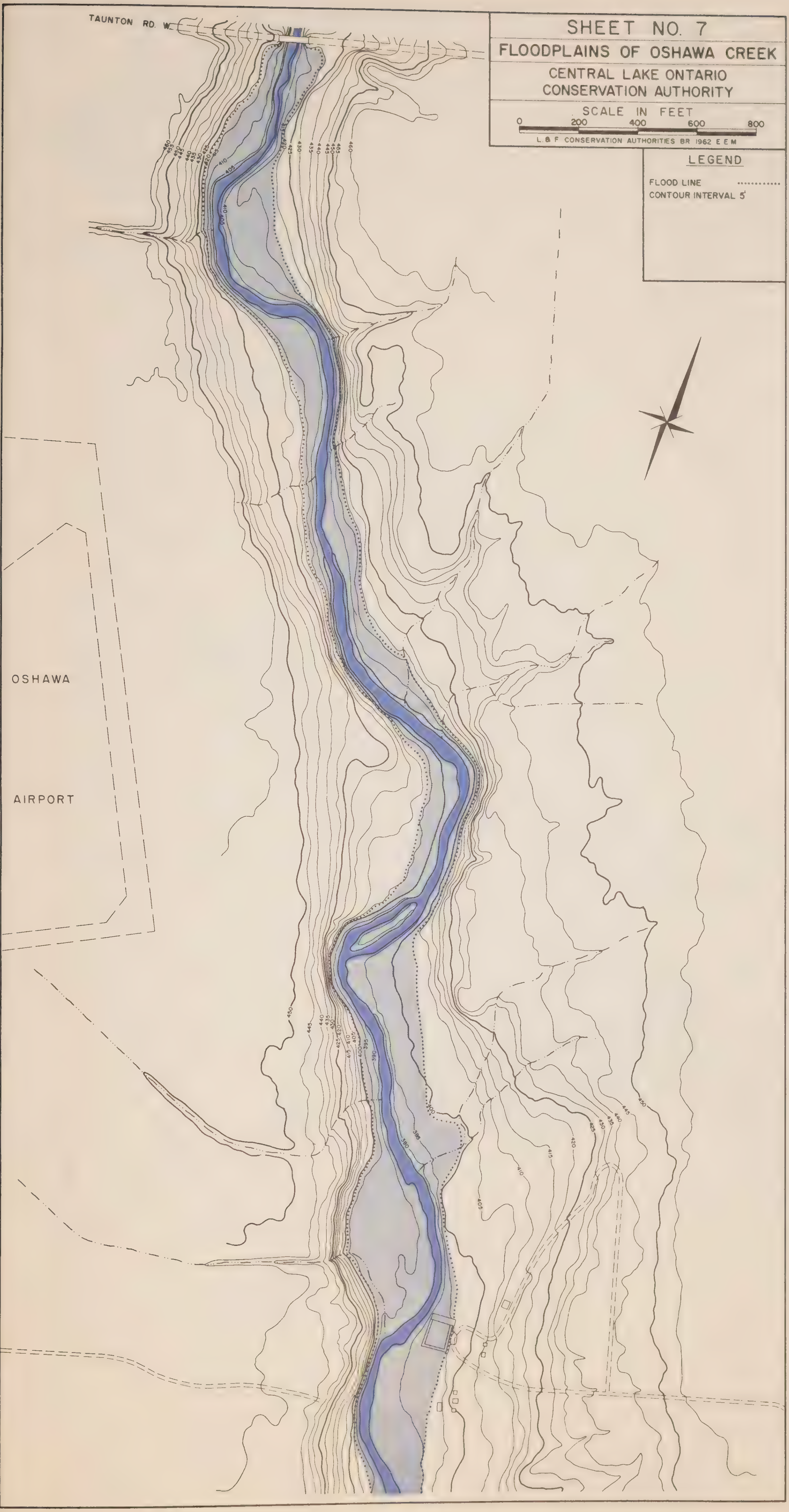

WINONA AVE
GLENWOOD
CRES.
BESSBOROUGH DR.
JONES AVE.
ROSSLAND RD.
NIPIGON ST.
W
BROOKSIDE DR.
SOMERVILLE AVE.
McLAUGHLIN AVE.
ARLINGTON AVE.
WESTMORELAND AVE.
BUCKINGHAM AVE.
WALMER RD
ANNAPOLIS AVE.
PARK RD. N
LEGEND
FLOOD LINE
CONTOUR INTERVAL 5'
SHEET NO. 6
FLOODPLAINS OF OSHAWA CREEK
CENTRAL LAKE ONTARIO
CONSERVATION AUTHORITY
SCALE IN FEET
0 200 400 600 800
L. & F. CONSERVATION AUTHORITIES BR. 1962 E.E.M.



SHEET NO. 6C

FLOODPLAINS OF GOODMAN CREEK

CENTRAL LAKE ONTARIO CONSERVATION AUTHORITY


SHEET NO. 7
FLOODPLAINS OF OSHAWA CREEK
CENTRAL LAKE ONTARIO CONSERVATION AUTHORITY
SCALE IN FEET
0 200 400 600 800
L. & F. CONSERVATION AUTHORITIES BR. 1962 E.E.M.
LEGEND
FLOOD LINE
CONTOUR INTERVAL 5'
TAUNTON RD. W.
OSHAWA
AIRPORT

SIMCOE ST. N.
TAUNTON RD W
LEGEND
FLOOD LINE
CONTOUR INTERVAL 5'
SHEET NO. 8
FLOODPLAINS OF OSHAWA CREEK
CENTRAL LAKE ONTARIO
CONSERVATION AUTHORITY
SCALE IN FEET
0 200 400 600 800
L. & F. CONSERVATION AUTHORITIES BR 1962 E.E.M.

CHAPTER 6

PHYSICAL CONTROLS

1. General

Control of floods by physical works such as dams and reservoirs, channel improvement and diversion is the alternative solution to flood plain zoning. However, where encroachment on the flood plain is already extensive or where other benefits may be derived, these works are often recommended. Wherever practical, dams and reservoirs should be given first consideration since they afford more opportunity for the multiple use of the water. Channel improvements and diversions provide local relief but often aggravate conditions downstream and do not conserve water, which in all likelihood will be required later.

In addition to providing flood control, reservoirs can serve the multiple purposes of increasing low flows during the summer, maintaining ground water levels and providing recreational facilities. Since land costs may become prohibitive if houses and other developments are allowed to encroach on suitable reservoir sites, it is well to note some of the better ones now in order that they may be preserved.

A number of potential reservoir sites were selected from an examination of the topographical sheets and the most promising ones were investigated further in the field. These are described below and their location is indicated on the watershed map, Figure 1. The sites considered were those which had potential for comparatively large volumes of storage that would provide flood control as well as other water requirements.

In considering the storage reservoirs for flood control purposes, two limitations must be borne in mind. First, the physical conditions of the watershed must be such that reservoirs of sufficient size can be constructed to store or retard the excess flood waters. Second, the reservoirs should be relatively close to the area to be protected. The

effectiveness of flood storage reservoirs diminishes rapidly as the distance upstream from the trouble area increases and may be totally ineffective if the intermediate uncontrolled area is too large. At least 65 per cent of the drainage area above the point of flooding should be controlled to provide adequate protection unless local channel improvements are contemplated as well.

It is not to be construed that the following are the only sites available on these watersheds, but they are considered to be the better ones. However, the storage is comparatively small and the cost of the dam in each case is high. This is due mainly to the steep gradients of the streams which necessitate the construction of high dams to obtain a reasonable amount of storage.

2. Dams and Reservoirs

In all, 16 possible reservoir sites were investigated. Five of the sites were surveyed and the storage and data shown for them are reliable. The storage capacities and other data for the remaining sites were determined from topographical sheets and are approximate only. A summary of the data for all the sites investigated is given in Table 6.

A brief description of the five surveyed sites is given below. In each case the dam would be of the concrete and earth-fill type and would be fitted with mechanically operated steel gates.

(a) Upper Devils Den Reservoir

The damsite is located on Lynde Creek at the crossing of the abandoned railway approximately 1½ miles south-west of the junction of Highways 7 and 12. A dam 81 feet high at this site would create a 122-acre lake with maximum depth of 76 feet and a storage capacity of 3,780 acre-feet.

The reservoir area has steep lateral slopes and is heavily wooded. No buildings or roads would be affected. Estimated cost of dam is $1,000,000, exclusive of land and other miscellaneous costs.

TABLE 6 - POTENTIAL RESERVOIR SITES ON CENTRAL LAKE ONTARIO WATERSHED

Stream	Reservoir	Drainage Area (Sq. Mi.)	Dam		Reservoir		
			Length (Feet)	Height (Feet)	Max. Water Depth (Feet)	Surface Area (Acres)	Storage (Acre Feet)
Lynde Creek	Whitex	20.2	500	30	25	48	680
"	Lower Devils Den	14.6	600	23	18	78	820
"	*Upper Devils Den	12.9	740	85	80	122	3,780
Oshawa Creek	*Lower Airport	36.7	720	55	50	175	2,980
	*Upper Airport	36.5	430	50	45	158	2,550
	Columbus	8.6	650	32	27	68	1,140
	Myrtle	3.3	650	32	27	61	900
Farewell Creek	Farewell	21.8	600	65	60	63	1,720
"	Solina	7.0	650	60	55	76	2,025
" (Black)	Black	6.5	600	20	15	340	2,800
Bowmanville	*Lower Gaud	29.9	880	60	55	154	2,990
"	*Upper Gaud	29.4	465	50	45	96	1,400
"	Enfield	6.6	500	18	13	43	320
" (Soper)	Lower Bowmanville	21.1	800	33	28	126	2,050
" "	Upper Bowmanville	15.7	700	42	37	102	1,500
" "	Stephen	14.2	500	30	25	39	520

* Reservoir sites surveyed. Data for other sites were obtained from 1/50,000 topographic sheet with 25-foot contour intervals. Upper Devils Den, Upper and Lower Gaud damsites profiled and ground-controlled for stereo projection. Upper and Lower Airport survey complete.

(b) Lower and Upper Airport Reservoirs

These sites provide well located storage but the costs would probably be high due to real estate values. The lower damsite is located on Oshawa Creek opposite the east-west runway of the Oshawa Airport. The upper damsite is located about 300 yards upstream at an abandoned railway immediately above Taunton Road in Oshawa. The topography is suitable for dams 55 and 52 feet in height respectively at these sites.

A short distance north of Taunton Road the main channel is joined by the east branch. Between this confluence and Taunton Road the west side of the valley has steep slopes and is heavily wooded. On the east side there are a number of frame cottages and a few brick houses. Of these dwellings 44 would be affected up to the 450-foot contour level. The total municipal assessment of these properties amounts to $62,165.

The easterly arm of the reservoir extends up the east branch of the creek about half a mile above Simcoe Street North. This part of the valley is well wooded, with some open pasture land. The valley land adjacent to Simcoe Street North is presently occupied by a few dwellings of which six would be directly affected by the proposed reservoir.

The westerly arm of the reservoir extends up the main channel through a partly wooded valley with fairly steep slopes for a distance of 1½ miles. At present there are no buildings on this section and it is used chiefly for pasture.

The estimated cost of constructing a dam at the lower site is $800,000 exclusive of land costs, and at the upper site $720,000.

(c) Upper and Lower Gaud Reservoirs

The upper damsite is located on Bowmanville Creek about 2½ miles above the Town of Bowmanville at an abandoned railway in Lot 16, Concession III, Township of Darlington.

Lower Airport Damsite on Oshawa Creek. This photograph gives some indication of the dense forest cover in the reservoir area.

Lower Gaud damline on Bowmanville Creek. The severely eroded steep bank is typical of erosion taking place along the stream channels in the Central Lake Ontario.

Spillway of a grist mill at Hampton on Bowmanville Creek. This dam is typical of the many small dams found in this area.

The lower damsite is approximately half a mile south of the upper site. The reservoir at this site would extend 2 miles north through a long narrow valley heavily wooded with steep slopes. Since this dam would be 20 feet higher than that at the upper site, it would combine both sites.

There are no buildings or roads within either site which would be affected. The estimated costs for these dams, exclusive of land, are $1,000,000 and $700,000 for the lower and upper sites respectively.

The dam and reservoir data for the other sites were obtained from topographical sheets and are approximate only.

3. <u>Channel Improvements</u>

In conjunction with flood plain zoning, floods can be alleviated by the removal of obstructions such as old bridges and abandoned dams, as indicated in the photographs. In addition to removing these obstructions, every effort should be made to ensure that adequate-sized culverts and bridges are constructed to ensure the free and safe passage of flood waters. It was found by calculation that any future flooding on Goodman Creek, a tributary of Oshawa Creek, would be caused by inadequate-sized culverts rather than by insufficiently sized channels. Figure 5 illustrates the backwater effect of narrow constrictions such as culverts and bridges.

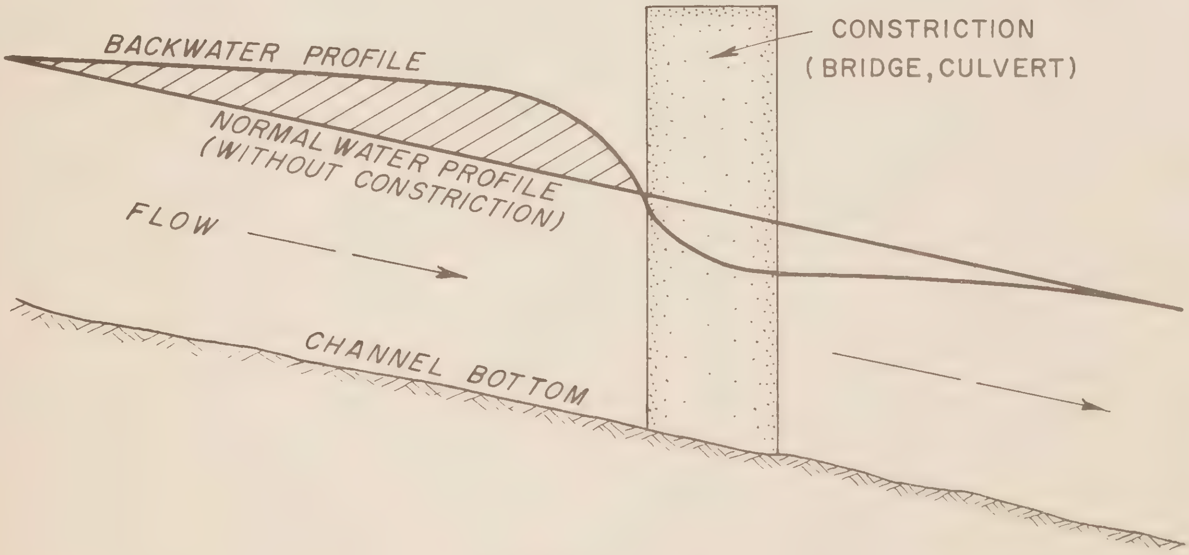
4. <u>Summary</u>

From the above cost estimate it can be seen that at present the expense would hardly warrant the construction of most of the reservoirs considered above. More economical protection can be offered by immediately zoning the areas subject to flooding. The Oshawa area with its steady pressure of urban development is particularly vulnerable. If development on the flood plain is not stopped, physical controls such as the Lower Airport Dam will have to be built at a cost of

1947 THAMES RIVER FLOOD AT QUEEN STREET BRIDGE, ST. MARYS
NOTE HOW THE BRIDGE CONSTRICTS THE FLOW RESULTING IN HIGH UPSTREAM FLOOD LEVELS AND HIGH SCOURING VELOCITIES AT THE BRIDGE.

PHOTO-COURTESY STRATFORD BEACON-HERALD

BACKWATER PROFILE CAUSED BY CONSTRICTION RESULTING IN UPSTREAM FLOODING



PROFILE

BACKWATER EFFECTS OF CONSTRICTIONS

FIG. 5

CONS. AUTH. BR., L.&F., Wm.M., 1963

$800,000, plus land etc., to provide a degree of protection to the community. Even the Lower Airport Dam would not protect the city completely from a flood of the magnitude of Hazel.

In addition, further flood troubles can be expected in the Whitby and Bowmanville areas if these communities expand into flood plain areas. The lack of sufficient flood control storage sites provides an additional reason for the immediate adoption of adequate flood plain zoning for the streams in the Central Lake Ontario area.

CHAPTER 7

SMALL RESERVOIRS

The benefits derived from small ponds are becoming increasingly appreciated throughout Ontario, both in heavily populated regions and in rural areas, as a source of emergency water supply. Flooded gravel pits and quarries, old mill ponds and newly constructed ponds are already being used to supply water to rural areas in times of drought. Suitable locations for community ponds are often found within the flood plain and such development is one of the more desirable uses for flood plain land.

A further asset of the community pond is its value for recreation and its ability to provide a habitat for various forms of wildlife. It can be stocked with fish and, providing conditions are favourable, wildfowl, muskrats and other forms of life can be encouraged to inhabit its waters.

Unfortunately, urbanization has proceeded at such a rapid rate throughout the Central Lake Ontario watersheds that property values have become extremely high. Nevertheless it is recommended that the Authority attempt a program for the acquisition of suitable community pond sites. In particular, this program should include the few remaining mill ponds with their accompanying mills. Many of these grist mills and saw mills would form a working museum of water power, particularly the Tyrone mill on Bowmanville Creek. The present mill owner has scoured Ontario in search of old belt-driven wood-working tools, such as planers, bandsaws and lathes. This mill would ideally serve as a historical record of water power for future generations.

Hampton Mills, located at the village of Hampton on Bowmanville Creek, is another mill with an attractive site.

Several factors should be considered when a community pond site is being selected. Easy access and good entrance roads are essential. The facilities should be able to

Mill pond at Hampton. Old mill ponds with some improvement would serve as a nucleus for attractive recreational areas.

Pond at headwaters of Soper Brook provides power for a saw mill.

Earth dam on Bowmanville Creek near Enfield. This dam illustrates two common faults of early earth dams — insufficient spillway capacity and steep embankments.

accommodate adequately the expected size of crowd. The water feeding the pond should be free from pollution, warm enough for comfortable swimming and should have a reliable flow. The type of pond selected, such as the excavated or impounded type, would depend largely upon the topography of the area.

The first mentioned includes all those in which storage is provided by excavating below natural ground level. These ponds are often called "dugouts" and can be adapted to almost any topographical condition. They are, however, best suited to relatively flat areas with heavy top soils. Such ponds may be fed directly by surface runoff or springs or through a by-pass from a natural watercourse or drainage ditch.

The impounding type of reservoir consists of a dam constructed across a valley or draw, above which water is stored. Favourable topography is essential for this type of pond. River flow and springs are the usual source of water supply for such ponds. It should be noted that by-pass ponds, which are common in the Central Lake Ontario watersheds, will not affect the movement of fish in the main stream, whereas a dam across a stream interferes with the movement of fish and tends to raise the temperature of the stream. Also, this type is subject to silting and may be shortlived unless adequate precautions are taken to reduce soil erosion upstream.

Where the water is cold, as is often the case with spring-fed ponds, provision should be made to allow for discharge from the bottom of the pond rather than from the surface. This removes the cold water and retains the warmer surface water for more comfortable swimming. It also helps to maintain lower water temperatures in the stream below the dam, which is essential for fish life.

There should be sufficient land around the pond site for picnic areas and playing fields for other sports. The area should be free of hazards such as old wells, submerged tree stumps, dangerous ruins and other objects which might en-

danger the lives of those using the area for swimming, boating, fishing, skating or other recreation. Finally, the site should be chosen to provide as much pond surface area as possible, and a depth of water of at least five feet.

Table 8 gives the location of many existing dams and location of damsites used in the past. This list is certainly not complete, but would form a basis for any plan for acquiring sites for small reservoirs.

SMALL DAMS OF CENTRAL LAKE ONTARIO

River or Tributary	Name or Locale	Location	Year of Const.	Hydraulic Head in Feet	Dam Length in Feet	Dam Height in Feet	Type	Original Use	Present Use	Present Condition	Owner	Developed H.P.	Remarks
Bowmanville Creek	At Enniskillen	Lot 21, Con. VII Darlington Twp.		18				Grist		Washed Out			
Bowmanville Creek	At Hampton	Lot 18, Con. V Darlington Twp.		18				Grist			Ch. Horn		
Bowmanville Creek	At Bowmanville	Lot 13, Con. I Darlington Twp.		23				Hydro Elec. Power	Hydro Elec. Power		F.C. Vanstone		
Bowmanville Creek	At Enfield	Lot 29, Con. VII Darlington Twp.	1960	10		10	Drop Inlet Emergency Spillway	Game Pond	Game Pond	Fair		100	
Tyrone Creek	1½ miles above Tyrone	Lot 10, Con. VII Darlington Twp.		16				Saw	Saw		C.W. Woodley		
Tyrone Creek	1 mile above Tyrone	Lot 10, Con. VII Darlington Twp.	1930				Conc.	Trout Pond		Out	H.W. Shappe		
Tyrone Creek	"Vanstone" at Tyrone	Lot 10, Con. VII Darlington Twp.	1846	23	250	25		Grist Mill			John Thornbeck		Rebuilt 1930
McKay's Creek		Darlington Twp.		15									
Mackie's	Mackie's	Lot 9, Con. V Darlington Twp.	1800's	12	200	25	Earth and Concrete	Saw Mill	Pond	Good	Douglas Mackie		W.L. Maintained at ¼ capacity
Soper	Bowmanville	Darlington Twp.		20				Grist Mills	Grist Mills			50	
Soper	Boy's Training School Bowmanville	E. of Bowmanville	1957	4.5	87	14.5	Gravity Concrete	Water Supply	Water Supply	Good	Crown		
Tributary of Soper		Lot 11, Con. N½ of III Darlington Twp.	1958					Water Supply Course	for Golf	Good			Operated by Pat Teo
Tributary of Soper	Barrett's Creek	Lot 9, Con. VII Darlington Twp.									L.D. Lundihn		
Bowmanville Creek	Haydon	Lot 14, Con. VIII Darlington Twp.		18						Washed Out			
Soper Headwaters		Lot 5, Con. VIII Darlington Twp.											
Soper Headwaters		Lot 6, Con. VIII Darlington Twp.						Trout Pond					
Oshawa Creek		City of Oshawa		21				Tannery				150	
Oshawa Creek		City of Oshawa		16								180	Steam Auxiliary
Oshawa Creek		City of Oshawa		26				Grist Mill				70	
Oshawa Creek	Goldman	Lot 13, Con. IV E. Whitby	1940	5±	60	6	Conc. and Earth	Swimming Pool	Swimming Pool	Good	A. Goldman		
Oshawa Creek	Camp Samac	Lots 10 & 11, Con. IV E. Whitby	1946	9-10	140	11	Conc.	Swimming Pool	Swimming Pool	Good	Oshawa Boy Scouts		
Oshawa Creek	James	Lots 10 & 11, Con. IV E. Whitby	1949		130	6	Conc.	Recreation	Recreation	Good	Geo. James		
Oshawa Creek	McLaughlin	Lot 7, Con. VIII E. Whitby	Prior to 1900		300	13	Conc.	Fish Pond	Fish Pond	Fair	R.L. McLaughlin		
Oshawa Creek	McLaughlin	Lot 7, Con. VIII E. Whitby	Prior to 1900		200	9	Conc. & Earth Fill	Fish Pond	Fish Pond	Fair	R.L. McLaughlin		
Oshawa Creek	Lyle	Lot 12, Con. IX E. Whitby	1930		150	8	Conc. & Earth Fill	Fish Pond		Out	Weil		
Oshawa Creek	Mason	Lot 14, Con. IX E. Whitby	1862		407	15	Wood & Earth	Mill	Mill and Fish Pond	Fair	Hazelwood		
Oshawa Creek	Lawrence	Lot 18, Con. IX E. Whitby	1928		181	6	Conc. & Earth	Fish Pond	Fish Pond	Fair	Calder		
Oshawa Creek	Alsop	Lot 18, Con. IX E. Whitby					Conc. & Earth	Fish Pond		Out	Parrot		
Oshawa Creek	J.E.H. Hammer	Lot 18, Con. VIII E. Whitby	1960		150	16	Gravity Earth				J.E. Hammer		
E. Branch of Oshawa Creek	Rucigay	Lot 8, Con. VII E. Whitby	1949	4.5	48	8	Non Reinforced Concrete	Irrigation	Irrigation	Good	V.G. Rucigay Oshawa		Operated Summer only
Lynde Creek	Sanderson	Lot 1, Con. IX Pickering Twp.	1956	5	150	7.5	Earth	Farm Pond	Farm Pond		W.O. Sanderson R.R. 1, Ashbury		
Lynde Creek	Huxtable	Lot S.W.1, Con. II Reach	1956	7.6		10	Earth	Private Pond	Private Pond		G.R. Huxtable R.R. 4, Uxbridge		
Oshawa Creek	Ranson	Lot 18, Con. VI E. Whitby					Conc. & Wood						
Oshawa Creek	Smith	Lot 18, Con. VI E. Whitby					Conc. & Wood						

TABLE 8

ABBREVIATIONS, EQUIVALENTS AND DEFINITIONS

Abbreviations

ac.ft.	acre-foot is equivalent to 43,560 cubic feet and is the quantity of water required to cover one acre to a depth of one foot.
B.O.D.	Biochemical Oxygen Demand is a measure of the oxygen that will be demanded by the material in the course of its complete oxidation biochemically. It is determined by the availability of the material as a bacterial food and by the amount of oxygen used by the bacteria during its oxidation.
c.s.m.	cubic feet per second per square mile is the average number of cubic feet of water flowing per second from each square mile of drainage area.
c.f.s.	cubic feet per second is the unit generally used to express discharge or the rate of flow.
G.S.C.	Geodetic Survey of Canada refers to the official datum of elevations above mean sea level as established by the Geodetic Survey of Canada.
M.P.N. or m.p.n.	most probable number
ML or ml	millilitre
P.P.B. or p.p.b.	parts per billion
P.P.M. or p.p.m.	parts per million
PH or ph	value measure of acidity or alkalinity

Equivalents

1 c.f.s.	= 6.25 imperial gallons per second
1 c.f.s. for 1 day	= 1,98347 acre-feet or approximately 2 acre-feet
1 c.f.s. for 1 year	= 724 acre-feet
1 ac.ft.	= 271,472 Imperial gallons

1,000,000 Imperial gallons per day = 1.86 c.f.s.

= 3,6836 ac.ft.

Definitions

AQUIFER is a water-bearing structure or formation.

BASE FLOW is that portion of the stream flow which originates from the ground water storage.

BOOST STORAGE is the storage required to increase the head of water over the discharge tubes in order that they may be able to discharge the required flow.

CAREX - sedges - grass-like plants common to wetlands.

CHANNEL CAPACITY or "IN BANK" FLOW is the maximum flow which is contained within the river banks and does not overflow the adjacent low lands.

CHANNEL CAPACITY STORAGE is the volume of water that must be impounded in order that the stream flow will not exceed the channel capacity flow or stage.

DAM is a structure in and across a river valley to impound, control and otherwise regulate the river flow.

DEAD STORAGE is the amount of water kept in a reservoir at all times for the purpose of protecting the artificial and natural water seals at the base of the dam.

DISCHARGE TUBE OR CONDUIT is an opening through the base of the spillway to provide means for discharging water when the water level of the reservoir is below the spillway level.

DRUMLINS are oval-shaped hills laid down by glaciers. They usually all point in the same direction.

FLOOD is an overflow or inundation coming from a river or other body of water.

FLOOD CONTROL is the prevention of flooding by controlling the high water stages by means of storage reservoirs, dikes, diversions or channel improvements such as widening, deepening and straightening.

FLOOD CONTROL STORAGE is the total volume of water that must be impounded during a given flood in order that the flood stage at a given point will not be exceeded.

FLOOD CREST is the maximum height or stage that the flood waters reach during any one flood period.

FLOOD HYDROGRAPH is a hydrograph which covers only the flood period or time interval during which the river flow is above the flood stage.

FLOOD RATIO is the ratio of peak flow to the average flow for the flood period.

FLOOD STAGE is an arbitrary level which varies from place to place and from season to season and is that level at which flood waters threaten to do significant damage.

FREEBOARD is the vertical distance between the maximum permissible water level and the top of the dam or dikes.

GROUND WATER is the portion of the subterranean water which occurs in the zone of saturation.

GROUND WATER STORAGE or RESERVOIR is a term used interchangeably with aquifer.

HORIZONS are the layers of soil, i.e., topsoil, subsoil, etc.

HYDRAULICS as applied to conservation deals with the measurement and control of runoff from river drainage basins.

HYDROGRAPH is a plot of flow against time and is an expression of the detailed runoff of a stream resulting from all the varying physical conditions which have occurred on the drainage area above the gauging station up to the time which it represents.

HYDROLOGY is the science which deals with the occurrence and distribution of water in its various forms over and within the earth's surface. As applied to conservation it deals more specifically with that portion of the hydrologic cycle from precipitation to re-evaporation or return of the water to the seas and embodies the meteorological phenomena which influence the behaviour of the waters during this phase of the cycle.

MORAINE is a ridge of sand or clay material deposited at the edge of, or between, lobes of a glacier.

OPERATIONAL STORAGE is additional storage space that is required to provide a safety factor to enable the controller to regulate the discharge from a dam so as not to exceed the channel capacity flow or stage.

PHYSIOGRAPHY is the description of the surface features of a landscape.

RATE OF RUNOFF is the rate at which water drains from an area. Usually expressed in cubic feet per second (c.f.s.).

RATE OF RUNOFF PER SQUARE MILE is the average number of cubic feet per second of water flowing from each square mile of area drained (c.f.s./sq.mi. or c.s.m.).

RESERVOIR is the body of water created by the construction of a dam.

RESERVOIR CAPACITY is the maximum amount of water that may be contained within the reservoir without exceeding the maximum permissible water level. Usually expressed in acre-feet.

RUNOFF is the amount of water which reaches the open stream channels and may be broadly defined as the excess of precipitation over evaporation, transpiration and deep-seepage.

RUNOFF DEPTH IN INCHES is the depth to which the area would be covered if all the water flowing from it were conserved and uniformly distributed over the surface.

SPILLWAY is that part of a dam over or through which the water is discharged.

SPILLWAY CAPACITY is the maximum amount of water that may be discharged over the spillway without exceeding the maximum permissible water level in the reservoir.

STREAM GAUGE is a measuring device used to determine the elevation of the water surface at selected points - usually a graduated rod fixed in an upright position and set to a known elevation from which the gauge readings are obtained by direct observation. An automatic type gauge is a mechanically operated recording instrument which gives a continuous record of water surface elevations.

SUMMER FLOW STORAGE is that volume of water remaining in a reservoir which may be used to augment the low flows and is equivalent to the maximum storage capacity of the reservoir less the dead storage, evaporation and ice losses and the space reserved for flash floods.

TILL is a heterogeneous mixture of clay, sand and stone material deposited by glaciers.

WATER or CLIMATIC YEAR is a 12-month period from October 1 to September 30. The water year was found to be a more convenient form than the calendar year for the purpose of stream flow studies as it groups together those months in which the water losses due to evaporation and vegetation demands are at a minimum (October - March) and those during which the losses are high (April - September).

WATER TABLE is the upper surface of the zone of saturation.

ZONE OF SATURATION is the portion of the earth which is saturated with water.